A monograph on KHAIR
(*Acacia catechu* Willd.)

DR. D.N. TEWARI
DIRECTOR GENERAL
INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION
DEHRA DUN, INDIA

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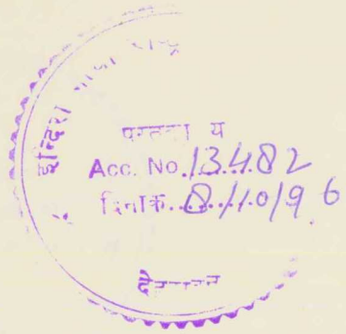

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PREFACE

Khair (*Acacia catehcu*) is a multipurpose deciduous tree with a light feathery crown. It coppices well upto moderate size and produces root suckers, particularly where the roots have been exposed. The tree becomes leafless during February-March and the new leaves appear during May, Flowers appears at the same time as new leaves and add to the beauty of trees. The trees continue in flower until July or August. The pods develop rapidly, becoming full sized by September-October. Mature seeds are ready for collection during January-February.

Acacia catechu is a classical example of pioneer species in the riverain succession. The species occurs naturally on sandy and gravelly alluvial ground along the banks of rivers and streams, on the riverain islands and on freshly laid down alluvium. The tree comes up naturally on recently laid down terraces of rivers, on freshly exposed soils, road cuttings, fresh embankment and landslips. It is amongst the principal tree species commonly recommended for afforestation programmes in the dry and frosty region for soil and water conservation as well as production of wood for manufacturing 'Cutch' & 'Katha'.

Although, khair is being grown in a number of countries (India, Nepal, Myanmar, Thailand etc.), the systematic information on all aspects is scattered and not readily available. The present monograph presents a detailed account on morphology, anatomy, silviculture, management, insects pests and diseases, utilization and extraction of 'Cutch' and 'Katha' etc. The monograph contains an exhaustive bibliography.

The monograph is intended as a step to enhance research and provide detailed information which will be of immense help to the research workers, foresters, katha factories, students, farmers and other interested in this species. I give my deepest thanks and appreciation to all those who helped me in bringing out this monograph.

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INTRODUCTION

HABIT, DISTRIBUTION AND HABITAT

A small or medium-sized deciduous tree with a light feathery crown, the branchlets armed with paired and recurved stipular spines. Bark thick, dark grey or greyish brown, rough, exfoliating in long narrow strips, brown and red inside. More commonly 12-15 m in height and 0.6 - 0.9 m in girth, with a clear bole of 2-3 m, usually crooked. When growing in more favourable localities, it has a moderately straight and cylindrical stem up to 30 m in height and 2.4 m in girth. A protected tree in Ramnagar Forest Division, U.P., measured in 1967-68 was 25.9 m in height and 1.8 m girth. Troup (1921) has recorded a tree of 3.2 m. in girth from the riverain tract in the U.P. Siwaliks.

Prain has distinguished 3 distinct varieties of the khair tree occurring as under:-

Var. catechu - Found chiefly in Punjab, Garhwal and Kumaon, Bihar, Orissa (Ganjam), and the Irrawady valley in Burma. This is the northern or Kumaon form. According to Talbot, it also occurs in N. Kanara and Konkan.

In the sub-Himalayan tract and the outer Himalayas, it ascends upto 900-1200 m elevation.

Var. catechuoides - Found chiefly in Sikkim terai, West Bengal and Assam and in upper Myanmar (Burma). This is the Burmese form.

Var. sundra (or chundra) - Found chiefly in the Indian Peninsula and in parts of Burma. This is the southern and western form occuring in the Deccan, Maharashtra, Gujarat, Madhya Pradesh and Rajasthan.

Khair occurs on a variety of geological formations and soils, though it undoubtedly thrives best on porous alluvium composed of sand and shingle. It is known to occur on granite, gneiss, schist, quartzite, shale, basalt, trap, limestone, conglomerate and laterite. It is common on sandy and gravelly alluvium and on loam or gravel with varying proportions of sand and clay. It grows also on black cotton soil. It is frequently found on arid shallow stony soil and grows even on sheet rock. On poor shallow soils composed of murram, or kankar, it grows where few other species are able to survive; this adaptability is seen also in parts of the sub-Himalayan tract, where it grows pure, though in stunted form, on poor hard soil composed largely of calcareous nodules, where hardly any other tree can exist. On stiff clay where the drainage is bad, it becomes stunted and tends to die off early (Troup, 1921).

Together with Sissoo, Khair forms the first tree association to colonise freshly formed islands in river beds and on freshly deposited sandy or gravelly alluvium soil along the banks of rivers, as very commonly observed in the bhabar tract of Dehra Dun Forest Division. There is ample water supply at a moderate depth, though the upper soil is generally very porous and dry during summer and almost devoid of humus.

It is essentially a tree of comparatively dry regions, though in its alluvial form, it extends into regions of heavy rainfall, as in the eastern sub-Himalayan tract where it is found in places with a rainfall as high as 3800 mm. Away from riverain tracts, it occurs in localities where the normal rainfall varies from 500-2160 mm. It develops to its maximum size in localities with heavy rainfall but it is decidedly xerophilous and grows in dry situations where few other species survive. In its natural habitat, the absolute maximum shade temperature varies from 40^{o}-49^{o}C, and the absolute minimum from minus 1^{o}-13^{o}C. (Troup, 1921). The mean daily maximum temperature in May, which is generally the hottest summer month, varies from 37.5^{o}-$43.5\ ^{o}$C; the mean daily minimum temperature in January, which is the coldest month of the year, varies from 1^{o}-21^{o}C.

Forest Types

Acacia catechu occurs in tropical moist deciduous forests, dry tropical forests and tropical thorn forests in the following sub-types as given by Champion and Seth (1968).

1. In low alluvial savannah wood land ($3/1S_1$) associated with *Bombax ceiba, Butea monosperma, Dalbergia sissoo* etc.

2. In Southern tropical dry deciduous forests (5A), khair occurs in very dry teak forests ($5A/C_1a$) and dry teak forest ($5A/C_1b$), associated with associates of teak. It also occurs in southern dry mixed deciduous forests ($5A/C_3$). Common associates are *Terminalia alata, Boswellia serrata.. Azadirachta indica* etc.

3. In northern tropical dry deciduous forests (5B), khair occurs in dry sal bearing forests ($5B/C_1$), dry Siwalik sal forest ($5B/C_1a$), dry peninsular sal forests ($5B/C_1c$) and northern dry mixed deciduous forests ($5B/C_2$). Common asslciates are *Shorea robusta, Terminalia alata, Terminalia bellirica, Boswellia serrata* etc.

4. Khair occurs in dry deciduous scrub ($5/DS_1$), associated with *Nyctanthes arbortristis, Dodonaea viscosa, Woodfordia fruticosa, Carissa opaca, Flacourtia indica, Lannea coromandelica* etc.

5. It occurs in edaphic climax types of dry deciduous forests as in *Anogeissus* forest ($5/E_1$ m) and Aegle forests ($5/E_6$).

6. It is also found in the seral type of dry deciduous forests as in Khair-Sisam forests ($5/1S_2$).

7. In southern tropical thorn forests ($6A/C_1$), *Acacia catechu* occurs associated with *Acacia leucophloea. Anogeissus latifolia, Azadirachta indica* etc.

As a plantation tree

On account of its hardness and value of wood, khair is an ideal species for the conversion of miscellaneous forests, containing inferior species and is being used to a considerable extent for afforestation in Uttar Pradesh. It plays an important part in the afforestation schemes of ravine lands of the drier parts of U.P. Experiments carried out to investigate the possibility of afforesting usar land with well defined kankar pan in U.P. indicate that the species is moderately suitable in mild usar, if planting is done in deep pits filled with better soil.

PHENOLOGY AND SILVICULTURAL CHARACTERS

The tree is leafless for a time during the hot season. In northern India, leaves are shed about February, the new leaves appearing towards the end of April or during May. By June, however, the khair forests have acquired their new delicate green feathery foliage, presenting a beautiful sight. Flowers appears at the same time as new leaves and add to the beauty of the trees. The trees conntinue in flower until July or August, sometimes even later. The pods develop rapidly, becoming full-sized by September or October, and turning from green to reddish green and then to brown; they begin to ripen by the end of Novermber and continue ripening during December and early January. The pods dehisce not long after ripening and commence falling in January, continuing to fall in the succeeding months. Some pods remain on the tree until the following October, by which time, however, the seed has become so damaged by insects as to be useless. (Troup, 1921).

Khair is a strong light-demander. Within its habitat, it is decidedly frost-hardy, though young seedlings are somewhat tender. In the abnormal frost of 1905 in northern India, it stood the frost better than most species, though young coppice growth was killed back. It is often found thriving in frosty grasslands where tender species succumb. Although decidedly xerophilous in character and capable of growing in dry situations where almost every other species fails to survive, it may suffer severely in

years of abnormal drought, as in 1899-1900 and subsequently in the Indian Peninsula, and in 1914-15 in Palamau, Bihar. In the abnormal drought of 1907 and 1908 in Oudh, it was unaffected on the low alluvial lands where it grows. (Troup, 1921).

The trees coppices well up to moderate size and produces root suckers, particularly where the roots have been exposed. Coppice shoots, however, require complete light for their development; under shade they are frequently not produced at all, the stools dying off. (Troup, 1921).

Although it withstands fire considerably growth is inhibited and many seedlings die back through the annual firing of grasslands.

Cuscuta attacks khair trees and kills them out. Several fungi damage khair trees, causing spongy heart rot, butt rot, mildew, white pocket rot, white spongy rot and spongy yellow heart rot.

Deer, pigs, wild elephants, porcupines, rats and domestic animals also damage young plants.

Beetles, larvae of borers, defoliators and sap suckers cause severe damage to the young living plants.

REPRODUCTION

NATURAL REGENERATION

Under natural conditions, the seed is disseminated by wind. The seeds adhere to the light pod valves after the pods dehisce and are often blown to a considerable distance from the trees. In alluvial tracts, dissemination of the seed is further effected by water. Though the seed itself is rather heavy, the pod with seeds get washed down and the seeds rubbed off among the sand and boulders of newly thrown up islands and banks.

Germination takes place in the beginning of the rainy season and the early development of the seedling is greatly favoured on loose soil free from weeds. Thus on alluvial sand or gravel, countless number of small seedlings may be found in the early part of the rainy season not only in the open but also under a comparatively dense cover. In the latter case they die rapidly owing mainly to shade and to damping off and by the end of the season, most of the seedlings disappear. In the open, a fair proportion survives provided the seedlings are protected from grazing.

The cattle are very fond of young shoots and closure of areas under regeneration has strikingly beneficial results. Frequently, there is a high mortality from drought, particularly if the soil is stiff or shallow and the roots have difficulty in penetrating it. The seed germinates readily with heavy rain and although germination takes place ordinarily at the commencement of the monsoon, it may begin earlier in the season in case of early heavy showers of rain; when this happens the seedlings generally die off or the germinating seed perishes in the ensuring spell or dry weather. Such mortality is particularly marked in the case of seeds germinating on the surface of the ground.

In wet and sodden grass, however, the seedlings damp off. Khair seed is very delicate and is at once killed by the slightest damage from fire. As the seed falls in

January and February, that is to say, just before the fire season commences, fires must be rigidly kept out from the areas under natural regeneration. The slightest carelessness in this respect may jeopardise a whole year's natural regeneration.

The freedom with which natural reproduction of khair springs up in alluvial riverain tracts is remarkable. The chief factors favouring it in such localities are the new loose soil free from heavy weeds and the abundance of light while the soil moisture obtained by percolation no doubt also assists the development of the seedlings.

As the crops become older and elevated above the river bed through changes in the course of the river, the conditions for natural regeneration change. The ground becomes harder and a dense undergrowth of *Adhatoda vasica* or other plants frequently makes its appearance. Under such conditions, natural reproduction is no longer possible and although it continues to take place where new alluvium is thrown up, it ceases under the old crops.

NURSERY PRACTICES

(a) Nursery site

Nursery work presents little difficulty, provided the nursery site fulfills the basic conditions of complete overhead light, a sandy loam soil, adequate irrigation and drainage. Soil working may be required especially in the case of heavier soils of the nurseries.

(b) Seed collection and storage

As a rule the tree seeds well almost every year and produces abundent crop of pods. The seeds adhere to the light pod valves after the pods dehisce and are often blown to a considerable distance from the trees. Seed fall takes place in the month of January and February. Khair seed is very delicate and is at once killed by the slightest damage from fire.

The seeds can be collected by lopping small pod-bearing branches in December or early January and spreading them in the sun for a few days. The pods are then heaped on a gunny bag and beaten with sticks. The pods are separated by shaking and winnowing in a flat basket.

(c) Sowing

It is advisable to sow the seeds in the year in which they are collected. Seeds are sown in the nursery in the month of April or May. Germination commences from about the 4th day after sowing and its completion may linger on upto 36 days. It is better to soak the seeds in cold water for 24 hours before sowing. In West Bengal, the pods are soaked in water for one or two days in May and then sown, there being no need to separate the seed.

(d) Irrigation

Irrigation is essential in the nursery till the out break of monsoon. The seedlings require daily irrigation with a precaution that the water does not accumulate at the roots of the plants.

(e) **Weeding**

One of the commonest forms of mortality in the case of seedlings in a heavy growth of weeds is the damping off to which they are subjected during the rains. For optimum growth, nursery should be kept free of weeds as these are liable to kill seedlings by suppression. It is therefore advisable to carryout regular weeding programmes especially in the rainy season.

PLANTING PRACTICES FOR THE SPECIES

(a) **Direct Sowings**

Direct sowing gives good results and is very easy. The methods of sowing vary under different conditions. In the grassy savannahs of Oudh, line sowings have proved successful in spite of a fairly tall growth of grass in the rains.

In areas flooded for long periods in the monsoon, khair should be sown on mounds at least 61 to 76 cm in height so that the seedlings do not remain submerged in water for a long period; a few weeks' submersion is not fatal.

Broadcast sowing has also been frequently tried,often with success: where suppression from weeds is to be feared, however, it cannot be compared with line sowings. The method which has succeeded best and is also very cheap is that of line-sowings with or without the raising of agricultural crops and is being adopted in several parts of India.

(b) **Taungya technique**

In Uttar Pradesh, large areas of miscellaneous forests of little value have been converted into plantations of valuable species such as *Acacia catechu* by line sowings with rains, weeding and fencing.

The annual coupe is clearfelled, the timber and firewood extracted and the area divided up into plots varying size from 0.4 to 1.6 ha and distributed among the cultivators. The cultivators then prepare the land for sowing, by burning the slash, uprooting the stumps if necessary and working the soil by hoeing or ploughing.

In many places unrestricted cultivation with any field crop is allowed in the first season. In the second season, the ground is prepared for the sowing of the selected tree crop in lines which may be kept 4.6 to 7.6 meters apart and the sowing of this and the field crop is done at the appropriate time. Both the forest crop and the agricultural crop grow up simultaneously and the cultivators undertake to keep the seedlings well weeded and to prevent the field crop from shading and suppressing the seedlings.

Cultivators may continue to take out field crops and tend the seedlings along with them from 1 to 3 years after the introduction of the tree crop, depending upon the fertility of the soil and the rate of growth of the seedlings. In the meanwhile they also get each year freshly cleared areas for sustained working. When the seedlings render taking out of field crop from an area uneconomic, that area is no longer cultivated and left for normal protection by forest staff. This system of cultivation promotes vigorous growth, the thorough working of the soil and the weeding causing the roots to strike deep down from the commencement.

Mechanised plantations

In the mechanised plantations, the annual felling coupes are of several hundred hectares. The standing forest is marked for clear-felling and sold by auction, with a stipulation that all the trees are felled by uprooting upto 60 cm depth and all the old stumps as well as the surface roots are dug out by the purchaser. This operation as well as the extraction and removal of all the produce and roots is under sale-deed to be completed in the winter season.

The area so cleared is given a hot burn and is first fully ploughed,then harrowed and finally ridged by tractors, the last operation consisting of laying out 45 cm high parallel ridges spaced 3-4 m apart centre to centre throughout the area. A system of roads and paths is then laid out, dividing the large coupe area into smaller plots of about 20-30 hectares. These plots are leased out for cultivation for 1-2 years, with the condition that the lessee will also look after, weed and tend the forest plants sown or planted along the ridges, together with his own crop.

Khair and other seeds are sown in the ridges in the 3rd week of June. The seed germinates with the out-break of monsoon and seedlings are weeded by the lessee.Three weedings have to be carried out by him in the first year, three in the second year and two in the third year. The area is already fenced in the summer of the first year and remains so till the plantation is about 6 years old.

On the termination of lease the fire-protection work is carried out by the forest department by laying out a number of fire lines round the coupe and plots and keeping them clear by cutting and burning the grass in late winter or spring. Sometimes the tall grasses in the intermediate strips between the ridges are hoed down by tractors to reduce their inflammability. The pressed grass may, after the plantation has become high enough, with all precautions, be control-burnt in cold weather.

(c) **Root and shoot cuttings (Stumps)**

Under optimum conditions, khair can also be propagated by stumps. The stumps should be made from seedlings about 15 months old raised in nurseries from seed sown in April of the previous year and irrigated till the break of monsoon. Cuttings should be made from well developed seedlings. The root and shoot should be 23 to 31 cm and 2.5 to 5.0 cm respectively.

The best size of stumps at the root collar is 10 to 15 mm in diameter. The seedlings under 10 mm in diameter at root collar do not make good cuttings, while seedlings thicker than 15 mm in diameter at root collar do not produce satisfactory shoots or fail to produce shoots. Planting of stumps should be done soon after the break of rains: delayed planting is not advisable. Under irrigated conditions stumps can be planted during March-April.

(d) **Entire planting**

In recent years entire planting of container plants has been successfully tried, particularly in Gujarat and Rajasthan. Polythene bags of the size 30 x 10 cm are suitable as containers. In Indonesia bamboo tubes have been reported used as containers.

CULTURAL OPERATIONS AND ITS CALENDAR

(a) Weeding

Repeated weedings are necessary in the first two or three years. Two good weedings are enough but sometimes a third is required in the first rains. One weeding may be necessary in the third year especially round the backward plants. The amount of weeding needed will depend on the site.

(b) Cleaning, Thinning etc.

Khair seedlings usually come up in a congested crop. In the early cleanings, plants may be spaced about 80 to 120 cm apart. Early thinnings are very important for the proper development of the crop. All shade, even lateral, must be removed. Normally the first thinning should not be delayed beyond the 5th year. If grown pure, it requires repeated climber cuttings. In *taungya* plantations, like that of North Gonda, the first cleaning is done at the age of 3 years. Subsequently thinnings are done at the ages of 5, 10, 15, 20 and 25 years. The first three thinnings are mechanical, in which a spacement equal to half to average crop height is aimed at.

In coppice crops, it becomes necessary to reduce the number of the several coppice shoots sprouting from a single stump to one or two within 3-5 years.

PESTS, DISEASES AND DEFICIENCIES

Khair seedlings are comparatively resistant to damping off disease in the nurseries,however, water logging may sometimes predispose the seedlings to damping off in the early stage of development.

(a) Root rot

Ganoderma lucidum (Leyss.) Karst. causes serious mortality due to root rot in reforested stands. Khair is susceptible to the attack of pathogen at all ages. The affected plants exhibit pale foliage followed by drying. Young plants are killed soon after infection while the mature trees die when most of the roots become affected.

The fungus produces thin white mycelial mat between the bark and wood and causes white spongy rot in the sapwood. Fruit bodies of the fungus develop at the base of affected trees which are stalked and corky. The stalk and upper surface are dark brown, and lightly zoned. Lower surface is white when fresh, turning light brown on drying and covered with minute circular pores. The spores are produced in abundance and are deposited on the adjoining weeds or grass as brown-red powdery mass.

The disease can effectively be checked by extraction of old stumps and cleaning of debris from the site, digging of isolation trenches in young plantations, planting of resistant species like *Bombax ceiba* and *Ailanthus excelsa* and mixed cropping (50 : 50) with resistant species.

(b) Heart rot

Fomes badius Berk. causes heart rot in khair and is common in all Khair forests, both natural and planted. Sporophores develop on the branches and trunk and are the main source of identification of diseased trees. They are perennial, hoof-shaped, sessile, hard and woody. Upper surface is brown or black, cracking with age.

Lower surface is dull brown with numerous minute pores. The fungus causes decay in the heart wood only. Sapwood remains healthy and free from infection. Initially the heartwood changes to deep brown in colour, but later becomes yellow, spongy and mottled. The heart rot increases with the age of tree and mature trees become unfit for extraction of cutch and katha due to its complete disintegration.

The disease can be managed to some extent by avoiding injuries to the trees and by periodically removing the sporophoces from the trees and burying them in the soil.

(c) Other diseases

Apart from the above, minor diseases, infect the foliage of trees. *Erysiphe acaciae* causes powdery mildew and *Microstromata acaciae* produces snowy-white tufts on the lower surface of khair leaves. Leaf rust by *Ravenelia tandonii* is common in North India. Among phanerogamic parasites Khair is attacked by *Macrosolen cochinchinensis* and in H.P. by *Loranthus* spp.

(d) Pests

Beetles, larvae of borers, defoliators and sap suckers cause severe damage to the young living plants.

Deers, pigs, wild elephants, porcupines, rats and domestic animals also damage young plants.

GROWTH YIELD AND MANAGEMENT OF THE SPECIES

The following statement shows the average rate of growth based on the measurements of 14 sample plots of Saharanpur, Rohilkhand, Ramnagar, Lansdowne, Haldwani, Baharaich and Terai and Bhabar Forest Divisions of Uttar Pradesh.

Age (years)	Average rate of growth Crop Height (m)	Crop diam. (cm)
10	11.27	12.2
20	16.15	18.8
30	18.59	22.4
40	19.81	25.4
50	20.73	27.7
60	21.34	29.7
70	21.64	31.2

The following table shows the total volume (Over Bark) and total volume (Under Bark) in cubic meters.

D.B.H. (cm)	Volume Over Bark (cu m)	Volume Under Bark (cu m)
10	0.13151	0.10084
20	0.18502	0.14195
30	0.49415	0.39836
40	0.86718	0.70860
50	1.26577	1.04037

The following table gives the yield of khair for good, moderate and poor site qualities. The table is based on the data of 10 sample plots distributed in Haldwani, Terai & Bhabar, Siwalik, Ramnagar, Lansdowne divisions and Silviculture Nursery at Clutterbuckganj (Bareilly).

Yield Table

Age (yrs)	Dominant Height (m)	Dominant Diam. (cm)	Number of Trees/ha	Total volume/ha (m^3)
Good Sites				
10	13.5	23.0	557	9.65
20	18.3	27.0	440	31.31
30	21.1	29.7	349	47.53
40	23.0	31.8	287	59.38
50	24.5	33.4	242	68.48
60	25.6	34.6	208	75.93
Moderate Sites				
10	10.6	21.1	557	3.23
20	15.3	25.4	460	18.00
30	18.1	28.3	376	33.34
40	20.1	30.5	312	45.47
50	21.6	32.2	264	55.12
60	22.8	33.5	227	62.97
Poor Sites				
10	8.0	18.8	557	0.57
20	12.3	23.5	460	8.22
30	15.1	26.5	396	19.89
40	17.1	28.8	336	31.30
50	18.7	30.7	288	40.96
60	19.9	32.2	250	49.25

ECONOMICS OF PLANTING THE SPECIES

(a) Exploitation cost of khair trees

The khair trees are got cut on job rates. Such cut timber is transported upto extraction path by manual labour. Cutting and collection charges fixed by the conservator of forest, Rewa during 1978-79 has been as under-

Girth class of khair trees (centimeters)	Cutting & collection charges (Rs. per tree)
46-52	0.60
53-60	0.70
61-67	0.80
68-75	0.90
76-82	1.00
83-90	1.10
91-97	1.20
98-105	1.30
106 and over	1.50

In Gwalior circle cutting and collection charges were fixed separately as under:

Girth class of khair tree (cm.)	Cutting charges (Rs. per tree)	Collection charges (Rs. per tree)
Upto 60	0.30	0.45
Over 60	0.50	0.75

For transportation of cut khair wood from the coupe to the depot (distance from 3 to 50 kms) haulage tenders are invited. In majority of the cases establishment of depot is attempted within 20 km to enable bullock-carts to carry out haulage work.

Depending on the distance and type of road, haulage charges vary from Rs. 1.25 to a maximum rate of Rs. 5.25 per tree.

(b) Revenue from khair wood

Revenue realisation from khair wood has substantially increased as per following details :

Year	Total Revenue from sale of khair tree (Rs.in crores)	Total Expenditure (Rs.in crores)	Net Revenue realised. (Rs.in crores)
1976-77	0.06	0.04	0.02
1977-78	1.48	0.14	1.34

(c) Other benefits

(i) An amount of Rs. 14 lakhs has been incurred during 1977-78 on wages in cutting and collection of khair trees inside the coupe area which has generated 3.5 lakh mandays employment to poor and needy people.

(ii) Cut khair wood was supplied to cooperative societies for manufacture of katha by country method. Local katha manufacturer got employment besides earning substantial wage and profits.

(iii) Many katha factories have been established.

(iv) New khair areas have been located and attempts are being made to bring them under scientific management for increasing cutch & katha production. Sapwood when mixed with the heartwood in various proportion yield cutch of very high commercial value. Sapwood is now also utilised for making pulp which is in great demand by pulp and paper and cardboard industry.

MARKETS, MARKETABLE PRODUCTS, USED AS RAW MATERIAL IN FOREST BASED INDUSTRIES

In India, State Forest departments are the major producers of khair wood. The wood is generally disposed off by the respective State Forest Departments/Forest development corporations at their sale depots.

Wholesale markets are mostly located in towns. These are permanent in nature where transaction take place daily throughout the year. In these markets (Mandis) the

wholesalers and commission agents play an important role in the sale of produce. During recent years, with the development roads, communication and transport, there has been a marked increase in the sales of khair wood at these markets (mandis).

In M.P., marked khair trees are cut in the coupe and if the trees are big then logged into pieces and numbered. Cut Khair wood is transported to depot where it is transferred to one of the following agencies:

(i) Given to advance purchaser who has tendered the highest rate on log basis for a particular coupe.

(ii) Given to cooperative societies or cottage industry for making katha by country method.

(iii) Supply of khair wood to Katha factories under contractual obligation.

(iv) In case of default by any of the above agencies khair wood is auctioned from the depot.

(a) **Khair wood used as raw material in Katha industries**

About 63,000 tonnes of khair wood (*Acacia catechu*) in India is annually consumed for manufacture of cutch & catechu. Chemically the products are catechin (katha) and catechutannicacid (cutch). A third article of commerce is also obtained in the shape of a white powder, known as kheersal, which appears as a deposit in the wood. It is used for medicinal purposes specially for cough and sore throat.

(b) **Yield of katha (cutch)**

The yield of katha and cutch varies considerably with the season in which the trees are felled and their girth, age and condition. The maximum yield of katha is obtained from trees felled in autumn and winter. Trees that are gnarled and crooked are reported to give higher yields than straight one. Trees of higher girth having white lines on them are preferred. Freshly felled trees also give higher yields than dried ones. Dead trees are unsuitable for extraction. Following table depicts yield of katha & cutch from 100 kg. of khair heartwood in different parts of the the country.

Yield of katha & cutch from khair wood
(Yield in Kilograms)

States	Factories		Small scale units	
	Katha	Cutch	Katha	Cutch
Andhra Pradesh	--	--	2	3
Bombay (including				
Maharashtra & Gujarat)	4.5	12	3-4	10
Madhya Pradesh	1.5 - 1.7	10-12	3	--
Uttar Pradesh	4.5	10.5	--	--
West Bengal	--	10.5	6.3	--

Average katha yield per trees by the country method (Handi method) is estimated as under :

Tree size girth in cm	Average katha yield in Kg
31-38	0.210
39-45	0.455
Over 45	0.900

(c) **Marketing of katha and cutch**

Katha is marketed in the form of irregular pieces and small square tablets or blocks of grayish brown colour, which when fairly pure, exhibit crystalline feature. No regular statistics are however, available for the widely scattered production of katha and cutch by the cottage scale manufacturers whose total production may safely be placed at least as equal to the factory production, if not more.

There are eight katha factories in U.P. located at Izzatnagar, Bareilly, Haldwani and Najibabad. It is in existence for past 50 years or so, while the other are of present origin. The factory at Izzatnagar processes about 10,000 tons of katha wood and produces about 500 tons of katha and 1,000 tons of cutch. The remaining factories utilize about 15,000 tons of heartwood and produce about 400 tons of katha and 1,000 tons of cutch. Their annual capacity varies from 1,000 to 3,000 tons of heartwood.

MARKETS AND DEPOTS

Following are some of the important khair wood markets and depots in Northern India.

Haryana	-	Sonepat, Chachrauli, etc.
Punjab	-	Roopnagar, Hoshiarpur,Pathankot, Dausya, etc.
U.P.	-	Kishanpur, Gorakhpur, Tulsipur, Najibabad, Gonda, Bareilly, Lakhimpur Kheri, Bahraich, Bijnore, Raiwala, etc.
Maharashtra	-	Chanda, Mhasrul, Kasa, Thane, etc.
Gujarat	-	Waghai, Songarh, etc.
Bihar	-	Hazaribagh, Monghyr, etc.
M.P.	-	Sidhi, Panna, Damoh, Sarguja, Sheopur, Sagar, Jabalpur, etc.

PHYSICAL PROPERTIES OF THE WOOD

Sapwood sharply distinct from heartwood, light yellowish-white or yellow. Heartwood deep red or reddish-brown, darkening on exposure; somewhat lustrous. The wood is hard to very hard, heavy to very heavy, average weight 1010 kg/m^2 at 12% moisture content; somewhat coarse and even-textured and straight to interlocked-grained. The wood has no characteristic smell or taste. (Rao & Juneja, 1971; Rao & Purkayastha, 1972).

ANATOMICAL STRUCTURE OF THE WOOD

A diffuse-porous wood with an occasional tendency for semi-ring porousness. Growth rings failry distinct, demarcated by a fine, interrupted line of parenchyma occasionally accompanied by somewhat larger vessels. Vessels small or moderately large to large, usually visible to the eye, few or moderately few to moderately numerous, mostly solitary or in multiples, almost always filled in the heartwood with either dark organge-brown gummy deposits or white specks of a powdery deposit known as kheersal which is visible to the naked eye; vessel lines conspicuous. Parenchyma usually visible to the eye forming 'halos' or 'eyelets' around the vessels or vessel groups and also in a fine interrupted line delimiting the growth rings. Rays usually fine, the wider ones just visible to the eye, rather closely spaced. (Rao & Purkayastha, 1972).

MECHANICAL PROPERTIES OF THE WOOD

The timber is very strong, very hard, very steady and moderately tought. The figures for its suitability as a timber for various purposes, expressed as percentages of the same properties of teak, for specimens from western U.P., are: weight, 147; strength as a beam, 128; stiffness as a beam, 119; suitability as a post or strut, 127; shock-resisting ability, 111; retention of shape, 116; shear, 155; surface hardness, 178; refractoriness (splitting co-efficient), 100; nail or screw holding property, 148. (Shekhar & Gulati, 1972). Mechanical properties of khair in the green and air-dry condition, have been determined for wood samples from Dehra Dun (U.P.) (Rawat & Rawat, 1960).

SEASONING PROPERTIES

The timber is highly refractory and liable to end-splitting and surface-cracking during seasoning. It seasons very slowly. It should therefore be converted soon after the rains and stacked properly under shade, well protected from rapid drying. Seasoning of thick boards or planks should be avoided wherever the timber is intended to be further converted into thinner sections.

The best result in kiln-drying with this timber will be obtained by using schedule No.VII for 2.5 cm thick planks and suitably increased humidities at the various moisture content steps in the schedule in case of thicker sections. Wherever practicable, slow partial air-seasoning to about 25% moisture content before finally taking up kiln-seasoning should be attempted. The pith should be removed from the pieces before seasoning.

Shrinkage percentage values for the timber from the green to oven-dry condition (Dehra Dun origin) are:- (Rawat & Rawat, 1960).

Radial shrinkage	=	2.3
Tangential shrinkage	=	4.1
Volumetric shrinkage	=	4.7

DURABILITY AND ADAPTABILITY TO TREATMENT

The sapwood is not durable. The heartwood is very durable and is described by Pearson as "one of the most durable Indian woods, which is seldom, if ever, attacked by white ants and fungi". There are several records of it having lasted for centuries in temples and it has also done well in harbour works. Natural durability 'graveyard' tests carried out at the F.R.I., Dehra Dun, have shown an average life of over 20 years. (Purshottam et al, 1953; Trotter, 1960).

SOURCES OF SUPPLY

The cutch logs are small and the timber is usually marketed in the small sizes required by the katha industry. The tree is very common in Uttar Pradesh, West Bengal, Madhya Pradesh, and parts of Punjab, Tamil Nadu, Maharashtra, Gujarat, Assam (including Meghalaya and Mizoram), Bihar , Orissa, Himachal Pradesh & Dadra Nagar Haveli.

UTILISATION OF SPECIES

(a) **Use as Timber , Poles, Pulp and Paper etc.**

Though khair is chiefly used as a source of katha and kutch, it is also a useful timber. It is much prized for posts in house construction and also for making rice pestles, oil and sugar-cane crushers, ploughs, tent-pegs, sword handles and keels and knees of boats. There is, however, a local superstition against it in parts of Uttar Pradesh on account of which it is not used in house construction.

Khair is a valuable economic structural timber, the heartwood being naturally durable. This species has been classified as "Super Group" timber suitable for large spans more than 12 m and is placed as the first choice of selection for permanent structures (I.S.I., 1962). It is eminently suitable for tools and tool handles, particularly for mallets and plane bodies. It is excellent for making spokes and hubs of wheels.

Sapwood of khair is a waste product in katha industry as it does not find at present any use except as a fuel. Since the katha manufacturers use the spent heartwood chips as a fuel in their boilers and bhattis, considerable quantity of the sapwood is literally wasted.

It can be seen from the results of chemical composition of the wood obtained at the F.R.I. Dehra Dun, that the sapwood of khair trees, if collected economically, can be profitably utilized for producing bleached cellulose which will find use in multifarious cellulose-based industries like MC, cellulose acetate, ethers, and even for paper and paper boards if made available in large quantities.

(b) **Use as fodder**

It is considered to be a good fodder tree and is extensively lopped to feed goats and at time cattle also. The plants are also browsed by cattle, rhinoceros, deer and elephant. The leaves contain 13.03-18.72% crude protein, 46.69-50.96% N free extract and 0.14-0.17% phosphorus. Total digestible nutrients are 46.33 kg. of dry material. The nutritive ratio is 15.0. The digestibility values are moderately high which shows that the leaves are feed for cattle on the basis of crude protein, crude fibre and tannin contents. The leaf fodder of *Acacia catechu* is rated as good.

(c) **Use as fuel**

It is also used as fuel and furnishes charcoal of good quality, the calorific value of moisture free sapwood being 5142 calories (9256 B.T.U.) and that of heartwood 4946 calories (8915 B.T.U.).

(d) **Medicinal Uses**

The different parts of the tree have a variety of medicinal uses, which in haemoptysis (spitting of blood). A paste of the bark is useful in conjuctivitis. The bark is reported to be useful in the treatment of snake bites.

Flowers : A mixture of flower tops, cumic, milk and sugar is useful in gonorrhea.

Wood : Cutch and katha obtained from the heartwood have great medicinal value. It is cooling, digestive and a very valuable astringent, specially in chronic diarrhea and dysentery, bleeding piles, uterine haemorrhages, leucorrhoea, gleet, atonic dyspepsia, chronic bronchitis, etc. It is also useful in cases of mercurial salivation, bleeding or ulcerated or spongy gums, hypertrophy of the tonsils, relaxation of the uvula, aphthous ulceration of the mouth, etc.

A mixture of catechu and myrrh (kathol) is usually prescribed as a tonic and as a galactagogue to women after confinement.

Kheersal is used as a remedy for chest diseases, especially for the treatment of asthama, cough and sore throat.

(e) **Katha (Catechu)**

The most important product obtained form *Acacia catechu* var. *catechu* proper is katha or catechu. This is obtained by boiling chips of heartwood with water. In India two varieties are marketed katha or pale catechu and cutch or dark catechu. As sold in the bazar, katha is found in irregular pieces or small square blocks of grayish colour, which on breaking show a crystalline fracture.

There is a very large internal demand for it for masticatory use in pan preparations and in medicine. Katha is regarded as astringent, cooling and digestive and is useful in sore throat, cough and diarrhea. Externally it is employed as an astrigent and as cooling application to ulcers, boils and eruptions on the skin. It is an indispensible ingredient of pan preparations. In combination with lime, it gives the characteristic red colouration resulting from the chewing of pan.

Dark catechu or cutch, which is mainly obtained as a by-product of the katha industry is marketed in the form of small cubes or blocks, rusty brown or dull orange in colour and of conchoidal fracture. It is used only for industrial purposes. It is largely used for dyeing cotton and silk and preserving of fishing nets, sailing ropes and mail bags; in water-softening and in the manufacture of stencils and printers ink.

(f) **Other uses**

Tanning : The astringent bark is sometimes used for tanning.

Lac : Khair is a very good host plant for growing the Katki or Aghani crop in alternation with the normal Rangeeni or Kusumi hosts. This species is unsuitable for

the Baisakhi or fethwi crops due to non-possession of sufficient vitality during the late winter and early got weather months to bear a lac crop. This species is best used for raising the Aghani crop and produces an encrustation equal in quality and quantity to that produced on kusum (*Schleichera oleosa*). The brood from the infestation of khair with kusum brood takes very well when used to infect kusum again in January-February. The resulting lac is of good quality.

Gum : The gum from khair is said to be of very good quality and is regarded as the best substitute for true gum arabic. The tears may be as large as 3 cm in diameter and pale yellow to dark amber in colour. It is not collected separately and is generally mixed up with other Acacia gums.

USES OF CUTCH AND KATHA

Cutch

It is used as a dyeing and preserving agent. Its chief industrial uses are in dyeing cotton and silk and in calico-printing. Cutch is also used for dyeing and preserving fishing nets and ropes and for dyeing canvas for boat sails and mail-bags to a reddish-brown colour. The use of cutch in the dyeing of ship's sails is said to be based on its excellent fastness and on its preservative action, preventing sea-water from corroding the canvas. Cutch dyes are usually preferred to coal-tar dyes as the former exhibit greater fastness to weather conditions and are less liable to mildew attack. The treatment of jute for rot-proofing with cutch and potassium dichromate has recently been patented. Cutch is also used for colouring pulp and paper. (Anon, 1970; Anon, 1948).

Katha

It is widely used as an indispensable ingredient in the preparation of chewing pan. It gives the characteristic red colouration in combination with lime resulting from the chewing of pan. (Anon, 1948).

Kheersal

This product is met with in some of the older trees in the form of a white powder or crystalline deposit in the wood cavities. It can be readily purified by crystallisation from hot water, and is used for medicinal purposes, specially for cough and sore throat.

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2

MORPHOLOGY AND DISTRIBUTION

The genus *Acacia* Mill. belongs to the family Mimosaceae (Leguminosae). It comprises about 800 species, which are distributed in the tropical and subtropical areas of the world. India accounts for about 30 species. Most of the species are trees but a few are twiners, others are hook climbers. Most of the Acacias are xerophytes and constitute a characteristic feature of the vegetation and landscape.

This genus is also known for many valuable products viz. Gum arabic (*A. senegal* (L.) Willd. - Tropical Africa & N.W. India); *Catechu* or cutch and Kattha (*A. catechu* Willd. - India). Biswas (1994) reported the use of *A. catechu* in agricultural implements, tans and dyes and as host tree for lac culture in Tehri Garhwal Himalayas; tan-bark (*A. mearnsii* De Wild; *A. decurrens* auct. - Australian black wattle, *A. pycnantha* Benth. - Golden Wattle of S.E. Australia, *A. dealbata* Link (Silver Wattle of Australia). *A. nilotica* (L.) Willd. ex Del. also yields tan bark which is largely used in India. Some species yield valuable wood especially Australian black-wood, *A. melanoxylon* R.Br., some bear sweetly scented flowers and are, therefore, used in perfumery e.g., *A. farnesiana* (L.) Willd. the cassie flowers of perfumery. *A. armata* R.Br. (Australia's Kangaroo thorn), *A. karroo* Hayne (South Africa), etc. form good hedges or sand binders. *A. dealbata* Link. is known as florists' mimosa and is of ornamental value.

SPECIES

Acacia catechu (Linn.f.) Willd., Sp. Pl. 4:1079. 1806; Baker in Hook.f. Fl. Brit. Ind. 2:295. 1878. *Mimosa catechu* Linn.f., Suppl. Pl. 439. 1781.

VERNACULAR NAMES

Assamese - *Khoira, Koir;* Bengali - *Khayer;* Gujarati - *Khair, kheriya baval;* Hindi - *Khair, khair babul;* Kannada - *Cachu, kagli, kugli* Marathi - *Kaderi, khair;* Oriya - *Khoiru;* Punjabi - *Khair; ;* Sanskrit - *Khadır;* Tamil - *Baga, karangalli, othalei;* Telugu - *Nalla sandra, sandra, sendra, tellatuma.*

ENGLISH NAME

The Cutch Tree, The Catechu Tree.

TRADE NAME

Khair

TREE MORPHOLOGY

A small or medium-sized deciduous tree, 12-15 m in height with a light feathery crown and dark brown glabrous branchlets armed with twin hooked prickles (Pl. 2.1, Fig. 1). More commonly found as a small tree 0.6 to 0.9 m in girth and usually with a crooked bole of 2-3 m. When growing in favourable habitat it has moderately cylindrical and straight stem upto 30 m in height and 2.4 m in girth. A tree has been measured to have a girth of 3.2 m (Joshi, 1983).

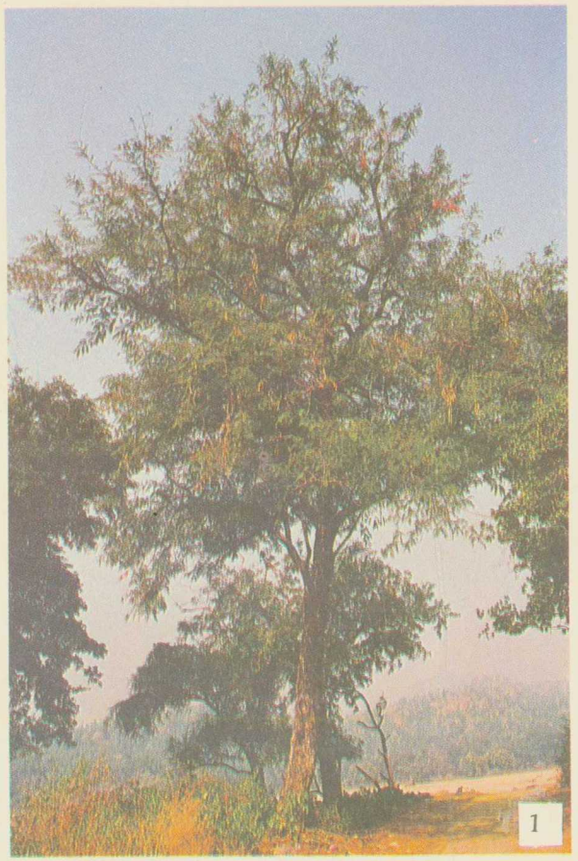
Bark is dark-brown or dark-grey, brown or red inside approximately 1.2-1.5 cm thick, rough, exfoliating in narrow rectangular flakes, which often remain hanging. Blaze very hard, vandyke brown and then deep pink (Pl. 2.1, Fig. 2&3).

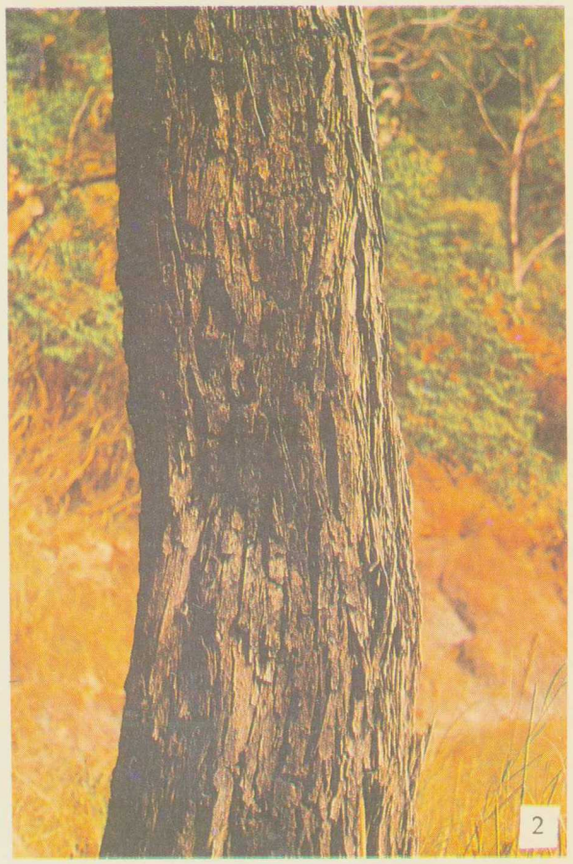
Branchlets armed with pseudo-stipular spines, which are found in pairs below the stalks of the leaves. Spines are strongly compressed with long bases, recurved, dark-brown or blackish in colour and about 5 mm long, spines are often lacking in old plants. Sapwood is yellowish-white; heartwood dark or light-red, very hard and durable (Pl. 2.1, Fig. 4).

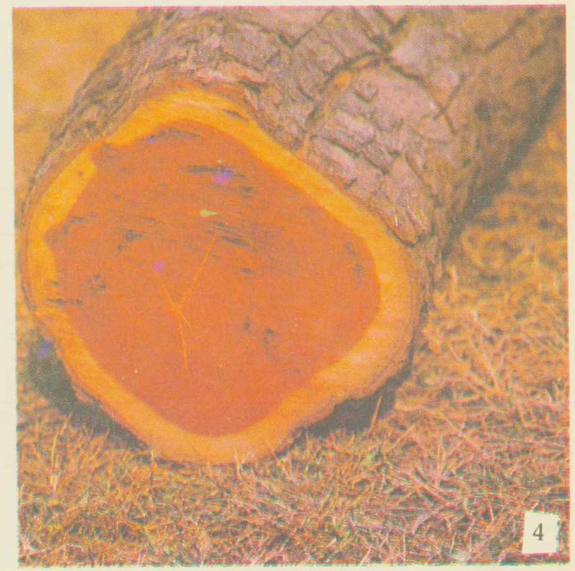
Leaves abruptly bipinnate, 10-18 cm long and have 20-40 pairs of pinnae. Rachis 8-15 cm long, more or less covered with fine hairs, often prickly with a large gland near the base of the petiole (Pl. 2.2, Fig. 2) and often smaller glands between the pinnae. Pinnae 20-50, 2-4 cm long. Leaflets 30-50 pairs on each pinnae, 5 to 10 mm in length and about 2.5 mm in width, oblong, crowded, upper surface bright, glossy, green, lower surface pale or rusty, sessile (Pl. 2.2, Fig. 1).

Flowers pale yellow or creamy-white, crowded in stalked, cylindrical spikes, spikes are 5-10 cm long, solitary or forming small axillary clusters. Flowers small, calyx bell shaped, 4 or 5 toothed or lobed. Petals 4 or 5 more or less united. Stamens very many usually more than 5o, much longer than the corolla, free or united near the base; anthers minute. Style thread-like; stigma minute (Fig. 2.1).

Fruit is a legume or pod, 5-7.5 cm long and 1.2 to 1.8 cm in width, thin, straight, flat, glabrous, oblong and stalked, acuminate at both ends, sutures slightly thickened, colour of mature pods is dark brown and shining (Pl. 2.2, Fig. 3).







Pl.2.1 Fig.1. A tree of *Acacia catechu* (khair). 2. Trunk of khair showing characteristic bark. 3. Trunk of khair showing blaze and inside of bark. 4. Cross section of khair wood showing of characteristic heartwood.

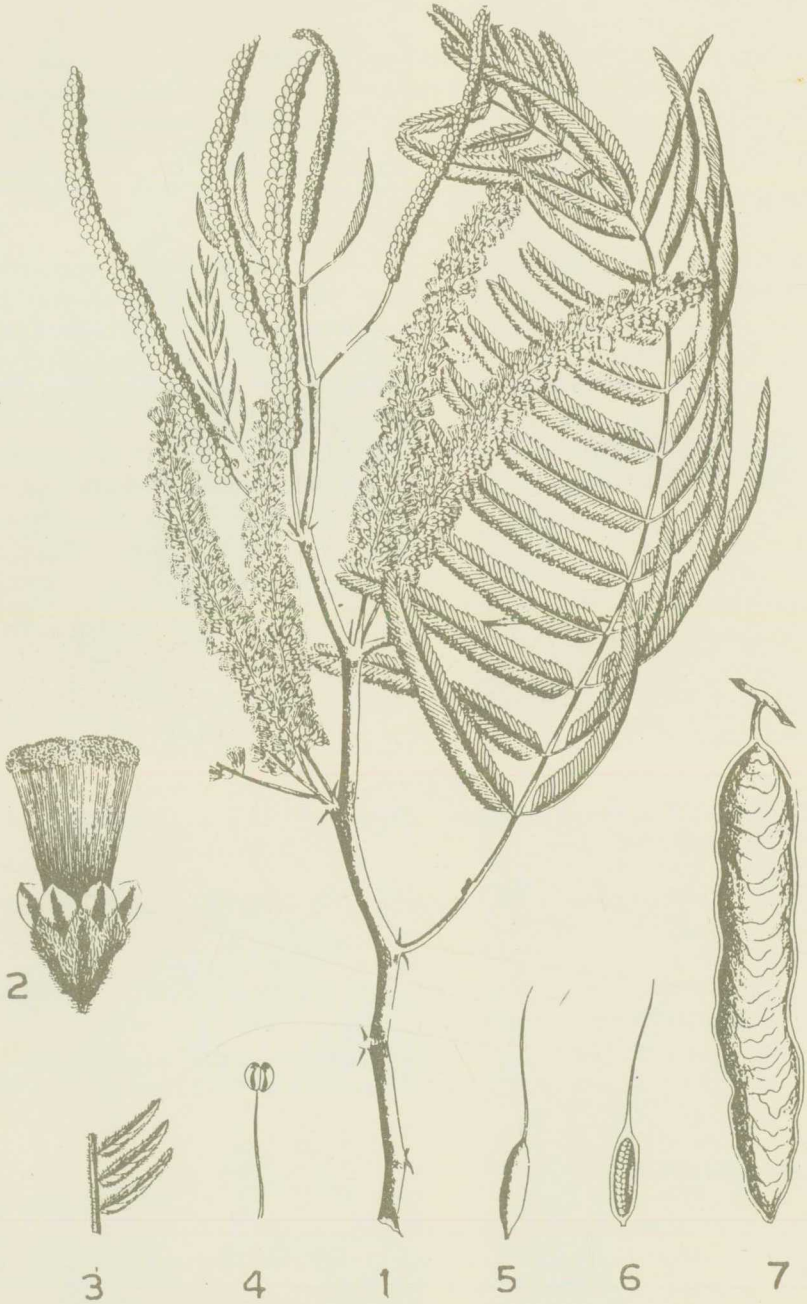


Fig.2.1 1. A plant twig with inflorescence (x1), 2. A flower (enlarged), 3. Part of leaf (x5), 4. Stamen (x15), 5-6. Pistal (enlarged), and 7. Pod (x1).

Seeds 3-8, in number about 5 mm in diameter, broadly ovate or orbicular, compressed greyish brown or dark greenish-brown, smooth, shining, moderately hard, with a tough and thick seed-coat, which becomes soft and pliant when soaked in water (Pl. 2.2, Fig. 4).

Germination is epigeous. The radicle emerges first and curves downwards; the hypocotyl then elongates and raises above the ground both cotyledons enveloped by the seed coat. The cotyledons expand, their colour changes from yellow to pale-green and the seed coat falls to the ground.

INFRASPECIFIC TAXA

Number of varieties belonging to *A. catechu* occurring in India has always been a matter of debate. Sir David Prain as early as 1898 identified three varieties, viz. var. *catechu* var. *catechuoides* and var. *sundra*. This conspectus has been followed by Duthie (1905), Talbot (1909) and Brandis (1921). Some other botanists, however, consider var. *sundra* as a distinct entity and have given it a specific status. Baker in Hooker's Flora of British India (1879) had treated *Acacia sundra* DC. as an independent species but according to his opinion it is scarcely more than a variety of *A. catechu* from which it can be distinguished by fewer leaflets and pinnae and the total absence of pubescence from the leaflets, rachises and calyx, by the latter being rather shorter and by the very dark brown colour of its branchlets. Bor (1953) treated *A. chundra* (Roxb. ex Rottl.) Willd. (Syn. *A. sundra*) as a separate species. According to some botanists *A. polycantha* Willd. is also a form of *Khair* but its bark is white and colour of the flowers is white.

Following are the well-known varieties/forms with their distinguishing features.

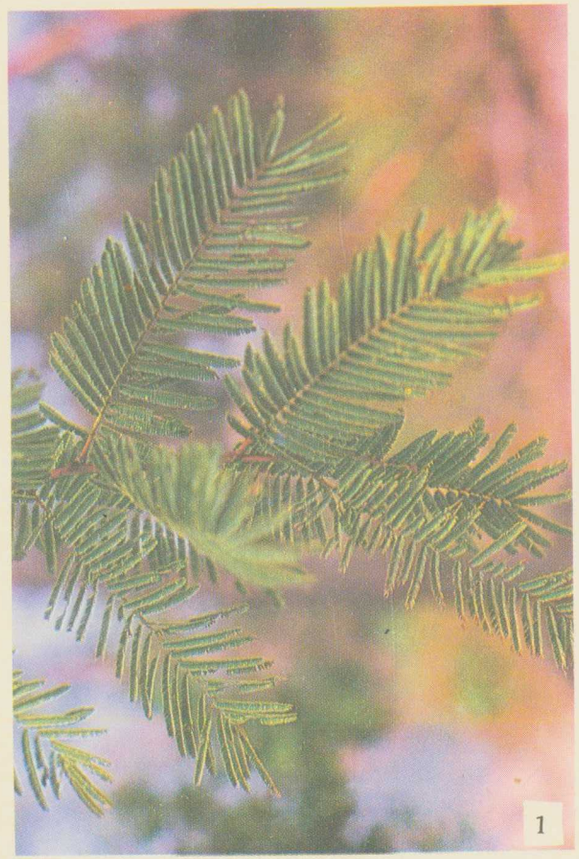
(i) var. *catechu* - Leaf rachis calyx and petals covered with spreading hairs. Leaflets pubescent. Branchlets brown, pinnae 20-40 pairs, Leaflets 30-50 pairs.

(ii) var. *catechuoides* - Calyx and petals without any hairs. Leaf rachis puberulous.

(iii) var. *sundra* - Status of this entity is debatable as some botanists treat it as a distinct species namely *A. chundra*. However, taxonomic confusion apart, this taxon can be identified in having glabrous leaf rachis, calyx and petals. Usually red branchlets. Pinnae 15-20 pairs and leaflets 20-40 pairs.

SEEDLING MORPHOLOGY

Primary root long, wiry, thickening considerably after a few months, cylindrical, tapering, whitish or pale-brown becoming dark brown; lateral roots few to numerous, short, fibrous or wiry, distributed down main root; nodules present. Hypocotyl distinct from root 13-20 mm long, terete, expanded in a ring at the base, white, turning green, glabrous or sparsely hairy in the upper part. Cotyledons shortly stalked, plano-



Pl.2.2. Fig.1. Bipinnate leaf of *A.catechu* with pinnae. 2. characteristic gland on the petiole. 3. Pods of *A.catechu*. 4. Dehisced pods showing compressed seeds.

convex, somewhat fleshy, 8-10 mm in diameter, orbicular, entire, base sagittate, glabrous, yellow, becoming green, obscurely 3-veined. Stem erect, somewhat zigzag at the nodes, thin, delicate at first, becoming wiry, green or reddish , young parts pubescent, elsewhere more or less glabrous. Leaves alternate, stipules minute, subulate, caducous. First leaf once paripinnate with 3-4 pairs of opposite leaflets, 5-6 mm long and 2.5 mm in width, rachis pubescent; subsequent leaves bipinnate, at first with one pair, then with two pairs of pinnae, each pinna at first with 3-5 pairs of leaflets, the number of leaflets increases in subsequent leaves.

DISTRIBUTION

Acacia catechu or the cutch tree is distributed widely throughout the greater part of India (Fig. 2.2) except in the most humid and the driest regions. It is common in the sub-Himalayan tract and outer Himalayas ascending usually to 900 m but going up to 1,200 m from Jammu to Assam. The record of the distribution of *Khair* shows that its varieties appear representative of one or other tolerably well defined area rather than overlapping one another (Prain, 1898). The var. *catechu* predominates in Jammu, Punjab, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa and Andhra Pradesh. This is also called northern or Kumaon form (Anon. 1973). This form is not found in the Eastern Himalayas. It also occurs in North Kanara and Konkan, out side India this is found in the Irrawady valley in Myanmar. The var. *catechuoides* is distributed in Assam, West Bengal and Sikkim *tarai* this variety is apparently absent in the Western peninsula. It is sometimes called Burmese form (Anon. 1973) owing to its occurrence in upper Myanmar (Burma). The var. *sundra* which is ambiguous as to its taxonomic status is confined chiefly to Deccan Gujarat, Rajasthan, Maharashtra, etc. It is also referred to as southern or western form. Apart from India this form is also distributed in parts of Myanmar.

Local Occurrence

(i) **Sub-Himalayan Tract** : *Khair* occurs commonly in this region from Indus to Assam ascending the valleys to 900 m and sometimes to 1200 m of altitude. From Yamuna eastwards it occurs either gregariously in the river or stream beds or in various types of dry mixed forests where it may be either gregarious or scattered. The riverian *Khair* forests of northern India come up on the new alluvium along the banks or in the beds of rivers and streams in the valleys of outer Himalayas and Siwalik range, these characteristic forests also spring up on deposits of sand, shingle and boulders extending some distance into the plains provided the alluvium does not acquire the nature of soft mud. Biswas (1977, 1985, 1994) mentioned about the natural occurrence of Khair in Tehri Garhwal Himalaya in moist and dry deciduous forests upto 1350 m in sub-Himalayan and Siwalik tracts. These *Khair* forests are either pure or mixed with *Dalbergia sissoo* and occasionally with *Acacia eburnea, Bombax ceiba, Albizia procera,* etc. Its typical grass associates are *Saccharam munja, S. spontaneum, Aristida cyanantha, Triraphis madagascariensis* and *Andropogon monticola*. There is also a dense undergrowth of *Adhatoda vasica* in these forests.

At higher elevation *Khair* is found mixed with hill species. Above Ratighat in Nainital hills at 1200 m it grows in river bed with *Quercus leucotrichophora* and *Pinus*

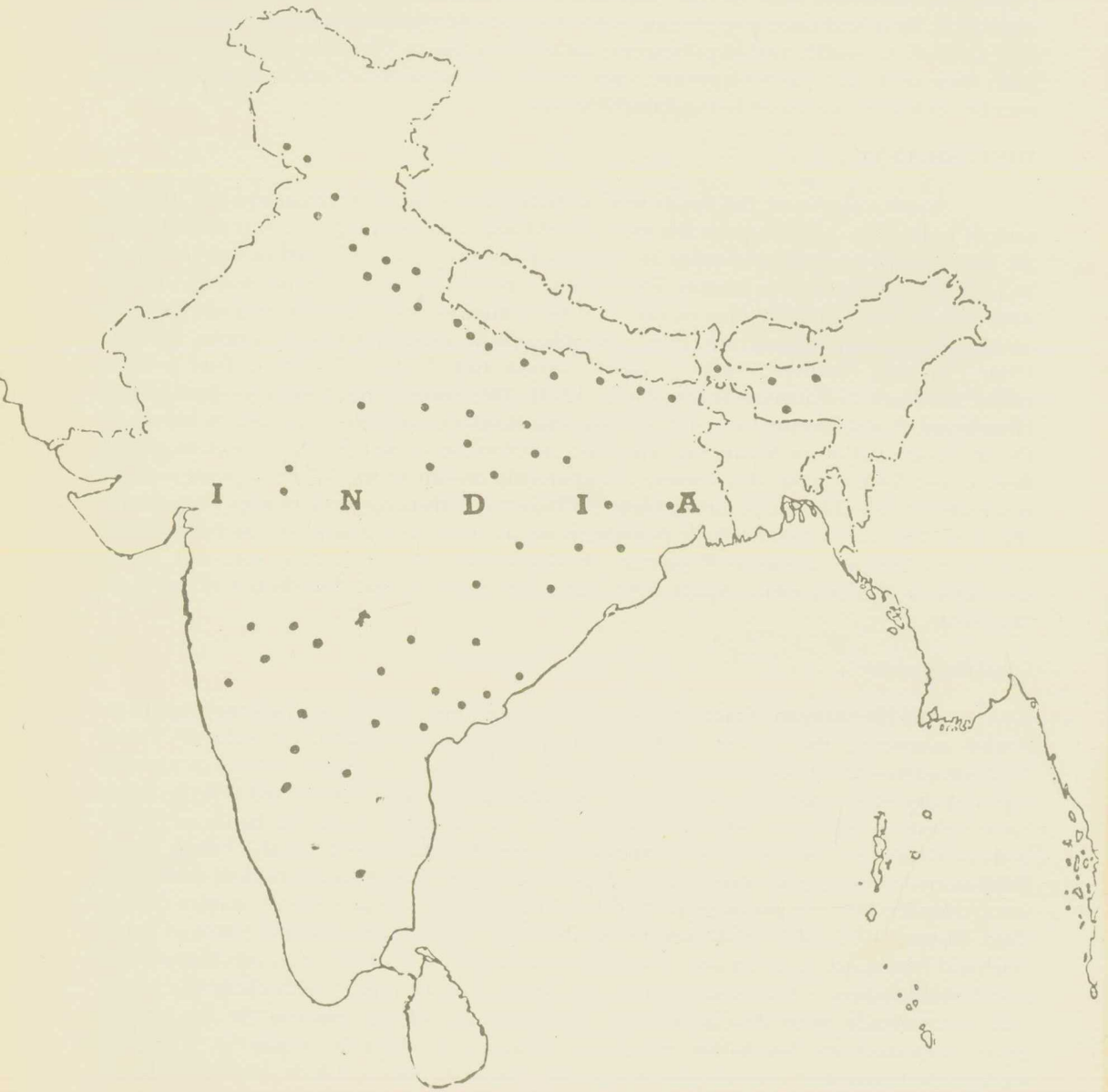


Fig.2.2. Map showing distribution of *Acacia catechu* (khair) (After Joshi, 1983).

roxburghii growing on the slopes down the edge of the river in the same locality it is found mixed with *Celtis australis* on the old riverian beds.

In non-riverian tracts it occurs either in scattered savannah lands or in various types of dry mixed forests, sometimes as a survival form former riverian forest which has become elevated recently above the river bed owing to the change in the course of river, but frequently on the land both flat and hilly which shows no such changes or on which it has established naturally after the land has ceased to be new alluvium. In these tracts *Khair* is frequently mixed with deciduous species viz., *Dalbergia sissoo, Bombax ceiba, Garuga pinnata, Lannea coromandelica, Ehretia laevis, Emblica officinalis, Ziziphus mauritiana, Bauhinia racemosa, Holarrhena antidysenterica,* etc. On drier and poorer ground its growth is stunted but survives under conditions which are unfavourable to the existence of almost every other species as seen in certain parts of submontane mixed forests of Gonda in U.P. In the poorest parts of these tracts *Khair* occurs pure as nothing else is being capable of growing under such conditions, but where the soil is somewhat favourable it is associated with stunted forms of *Diospyros montana, Anogeissus latifolia, Buchanania latifolia* and *Nyctanthus arbor-tristis.*

West of Yamuna the riverian type of *Khair* forest is scarce, being confined to a few localities e.g. in parts of Kangra valley, but the tree is quite common on the dry foot-hills often associated with *Acacia modesta* and extends in some places into the region of *Pinus roxburghii.*

In sub-Himalayan tracts it occurs in the localities where normal rainfall varies from 65-450 cm.

(ii) **Indian Peninsula** : *Khair* is common throughout the greater part of the peninsula in dry type of mixed forests on a variety of geological formations and soils.

In Madhya Pradesh and adjoining areas it occurs in open grass-lands and in teak forest of a dry type as well as in the forests devoid of teak, its commoner associates being *Terminalia tomentosa, T. chebula, Lagerstroemia parviflora, Anogeissus latifolia, Diospyros melanoxylon, Ougeinia oujeinensis, Buchanania latifolia, Ziziphus mauritiana, Z. xylopyra, Aegle marmelos, Lannea coromandelica, Butea monosperma, Acacia leucophloea, Cochlospermum religlosum, Gossypium* spp., *Holarrhena antidysenterica, Emblica officinalis, Chloroxylon swietenia, Soymida febrifuga, Cleistanthus collinus, Gardenia latifolia, G. lucida,* etc. as well as *Dendrocalamus strictus.*

On dry hills it grows with *Boswellia serrata* and *Sterculia urens,* in places where soil is poor and shallow, with sheet of rock cropping out. On trap or gravely soil its associate is *Hardwickia binata.* In central part of the peninsula it is one of the commonest species in a poor stunted type of forest where soil has an excess of calcareous nodules on the surface. Its chief associates here being *Chloroxylon swietenia, Soymida febrifuga, Diospyros melanoxylon, Buchanania latifolia* and *Terminalia tomentosa.*

In Maharashtra and Gujarat, it occurs in dry open thorn forests associated with many of the species already mentioned as well as with *Prosopis juliflora* and sometimes with *Acacia nilotica* sp. *indica*; here also it forms poor stunted type of forests on dry

calcareous or *murram* soil. It ascends to 1100 m of altitude in Khandesh Akrani, and it occurs nearly pure in larger or smaller patches on the low level laterite near sea coast in North Kanara and Konkan. In Dangs of Surat it is common but not so plentiful as it once was, having been worked at one time for catechu manufacture.

In Chhota Nagpur (Bihar), it is found in dry mixed deciduous forests as well as frequently in association with sal. It occurs in the dry forests of Central India and Rajasthan where it often grows on mere sheet rock in hilly tracts. In Rajasthan it is common and grows with *Anogeissus pendula, Albizia odoratissima, Boswellia serrata, Acacia leucophloea* etc.

In Southern states, it is common in dry mixed forests often on dry stony soil associated with *Acacia leucophloea, Albizia amara, Chloroxylon swietenia, Prosopis spicigera, Cassia fistula, Anogeissus latifolia, Ziziphus mauritiana, Z. xylopyra, Santalum album, Hardwickia binata* etc.

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3

ANATOMY

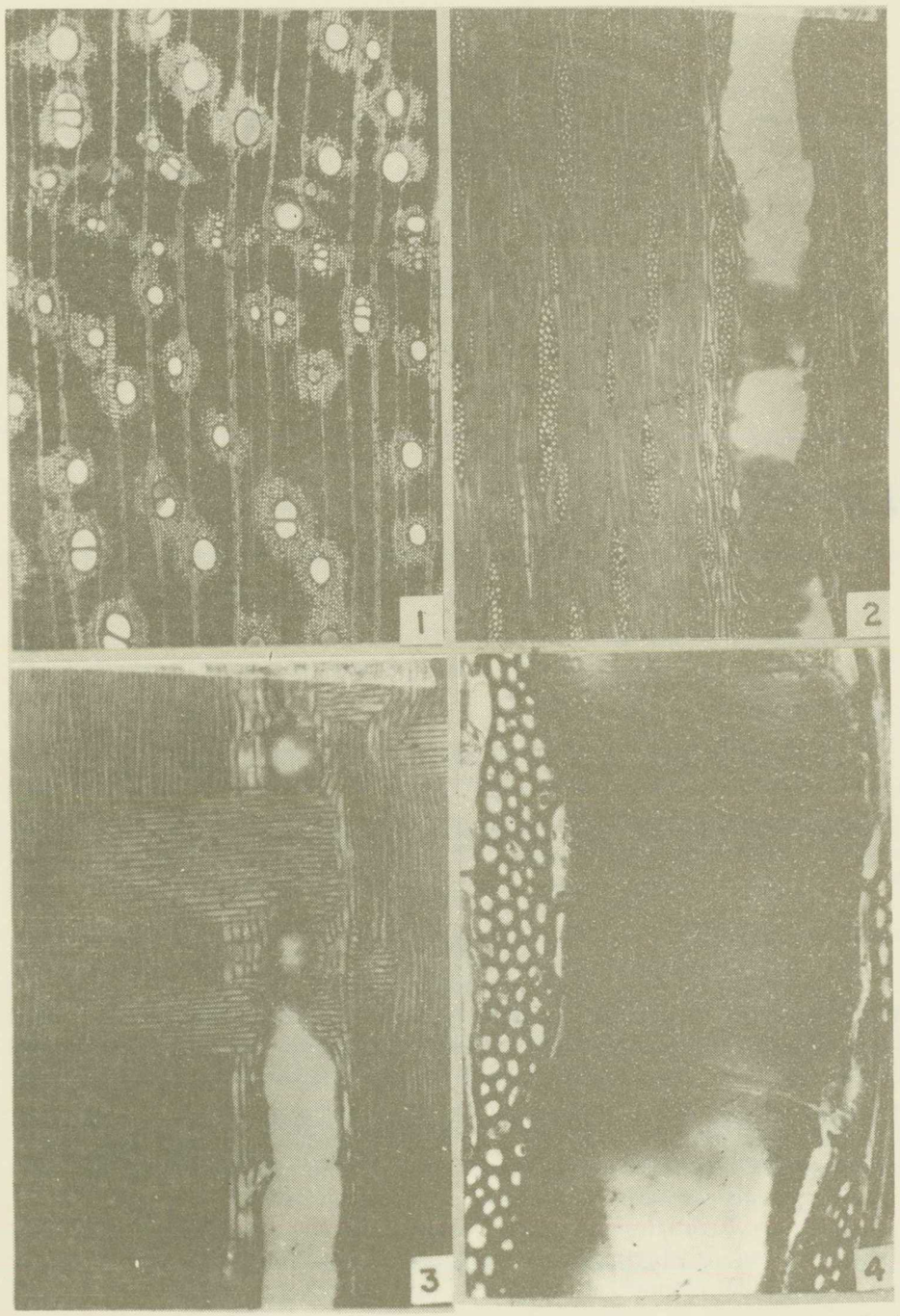
WOOD

General features

Sapwood distinct from heartwood, light yellowish-white. Heartwood reddish-brown to dark brown; somewhat lustrous. Wood hard to very hard, heavy to very heavy, average weight 1010 kg/m^3 at 12 per cent moisture content; somewhat course and even-textured with straight to interlocked grained (Ramesh Rao & Juneja, 1971).

Gross structure

A diffuse-porous wood with an occasional tendency for semi-ring porousness. **Growth rings** fairly distinct, demarcated by a fine, interrupted line of parenchyma, occasionally accompanied by somewhat larger vessel, 1-6 per cm. **Vessels** small or moderately large to large usually visible to the eye, few or moderately few to moderately numerous (1-13 per mm^2), somewhat evenly to unevenly distributed, mostly solitary or in multiples of 2-3, occasionally in small clusters, oval or round in outline, almost always filled in the heartwood with either dark orange-brown gummy deposits or a white powdery substance (Kheersal), which is visible to the naked eye; vessel lines conspicuous. **Parenchyma** usually visible to the eye forming 'haloes' or 'eyelets' round the vessels or vessel groups, sometimes connecting or enclosing adjacent vessels in oblique or tangential manner, also in a fine, interrupted line demarcating the growth



Pl.3.1 Fig.1. Cross section showing small to medium-sized vessels, thick walled fibres and aliform to confluent parenchyma. 2. T.L.S. showing 2-5 seriate rays. 3. R.L.S. showing homogeneous rays and chambered crystals in parenchyma. 4. T.L.S. showing vestured intervascular pittings.

rings. **Rays** usually fine, the wider ones just visible to the eye, rather closely spaced (Ramesh Rao & Purkayastha, 1972).

Microscopic structure

Pearson and Brown (1932) studied the minute structure of the wood in detail. Vessels upto 265/^{um} in diameter, perforation plates simple, intervascular pits elliptical to oval, vestured, 5-7/^{um} in diameter, pits leading to rays and parenchyma slightly larger than intervascular pitting 6-8/^{um} in diameter, vessel-members 65-300/^{um} in length, truncate or abruptly tailed on one or both the ends, tyloses absent; chalky deposits very abundant, occluding vessel segments and forming more or less continuous lines along the grains, reddish-brown gummy infiltration common in heartwood, plugging the vessels. Parenchyma abundant, predominantly paratracheal, vasicentric as thin sheath round the vessels and extending side ways connecting the adjacent vessels tangentially or often obliquely, apotracheal as few scattered cells and also as fine tangential lines delimiting growth rings, cells arranged in radial rows, generally tangentially flattened containing reddish-brown gummy infiltration and usually with crystalliferous locules each containing solitary rhomboidal crystals. Fibres round in transverse section, irregularly aligned, average maximum diameter and wall thickness 25/^{um} and 6/^{um} respectively, 335-1500/^{um} long interfibre pits very sparse, simple and non septate. Rays 1-6 (mostly (3-4) seriate, 6 per mm.(t), homogeneous, uniseriate rays 14.5/^{um} in width, upto 12 cells or 157/^{um} in height composed of procumbent cells, multiseriate rays 57/^{um} in width upto 30 cells or 400/^{um} in height composed of procumbent cells, reddish-brown gummy infiltration abundant, crystals absent (Pl. 3.1, Figs. 1 to 4).

FORMATION OF GROWTH RINGS

Chowdhury (1939) studied cambial activity and formation of growth rings in *Acacia catechu* and recorded the following observations. In October, 1930 the trees were in full crown and the cutting showed diameter growth activity both in the branches and in the main bole. Outwardly, little change was observed in November and December. By the middle of November cambium cells became in active, but the cells of the xylem were not fully lignified up to the end of the year.

In the second week of January, 1931 leaf-shedding started. Microscopic examination at that time showed complete lignification of the late wood. During February and March, leaves continued dropping, and by the first week of April the trees were entirely leafless. In early May, new leaves started coming out at the tips of the branches, especially on the south side. Cuttings taken at this time showed that the cambium was undoubtedly swollen but growth activity had not yet started. During the month of June, leaves continued coming out and expanding but anatomically little change was noticed. By the first week of July the crown had developed to almost full size and inflorescences were out. Diameter growth was noticed at this time in the young branches. But in the main bole cambium cells were expanded without any sign of growth activity. Two weeks later growth was recorded in all cuttings both from young branches and the main bole. From this time up to the middle of September diameter growth continued at a good rate. Thereafter, the rate of growth became slack, and pods were

seen on the top branches. During October, no further change was noticed, either externally or internally. The fibres formed at this time were comparatively thick-walled. In the first week of November, diameter growth seemed to have stopped in the main bole and twig. Parenchyma cells were the last tissues to be formed at the end of the growth season and they often contained crystals. By the middle of December, the leaves started dropping, and cuttings showed complete lignification of the current year's latewood.

During January and February, 1932 leaves continued dropping, and by the middle of March the trees became leafless. About the third week of May, the top branches began to show signs of leaf renewal. At this time cambial activity was noticed in the twigs examined, but in the main trunk the cells were still dormant although they were somewhat swollen. By the middle of June, trees were in almost full crown, and growth became active in the main bole. Growth continued at a fast speed during July and August. In September and October, growth was proceeding at a slow speed, and in early November it stopped altogether. As in the previous year, a tangential band of parenchyma cells terminated the season's growth. By the third week of December, leaf shedding was noticed and the current year's wood was fully lignified.

In January and February, 1933 leaves continued dropping, and by March the trees became entirely leafless. In the first week of April, new leaves were found coming out at the top. At this time a large number of cuttings were taken. One-year-old twigs showed a slight swelling of cambial cells but not growth. Two-and three-year-old twigs and the main bole did not show even swelling of the cambium. On subsequent visits no outward changes were noticed, and the trees remained more or less in the same condition till the middle of May when new leaves were coming out in a flush. Cuttings from twigs showed that growth had started in some of them not all, and that growth was not active all over the cambium but in small patches. Examination of cuttings in early June revealed cambial growth activity in one-year, two-year but not in three-year-old twigs. On the other hand, in some four-year-old twigs the cambium had become active. In the main trunk growth was active in small patches - not all over. Leaves continued to grow during June, and the inflorescences were out, while the diameter growth was progressing very slowly. By the middle of July, the trees had developed to almost full crown and growth appeared to be fast. The same rate of growth was maintained throughout August. In September growth became slow and the pods started turning brown. By the middle of October, the trees had some dry fruits, and cuttings from the twigs showed that the cambium had become inactive, although growth was progressing very sluggishly in the main bole. In early November, growth stopped all over the trunk. Once again, the seasonal growth was terminated by a narrow band of parenchyma cells.

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4

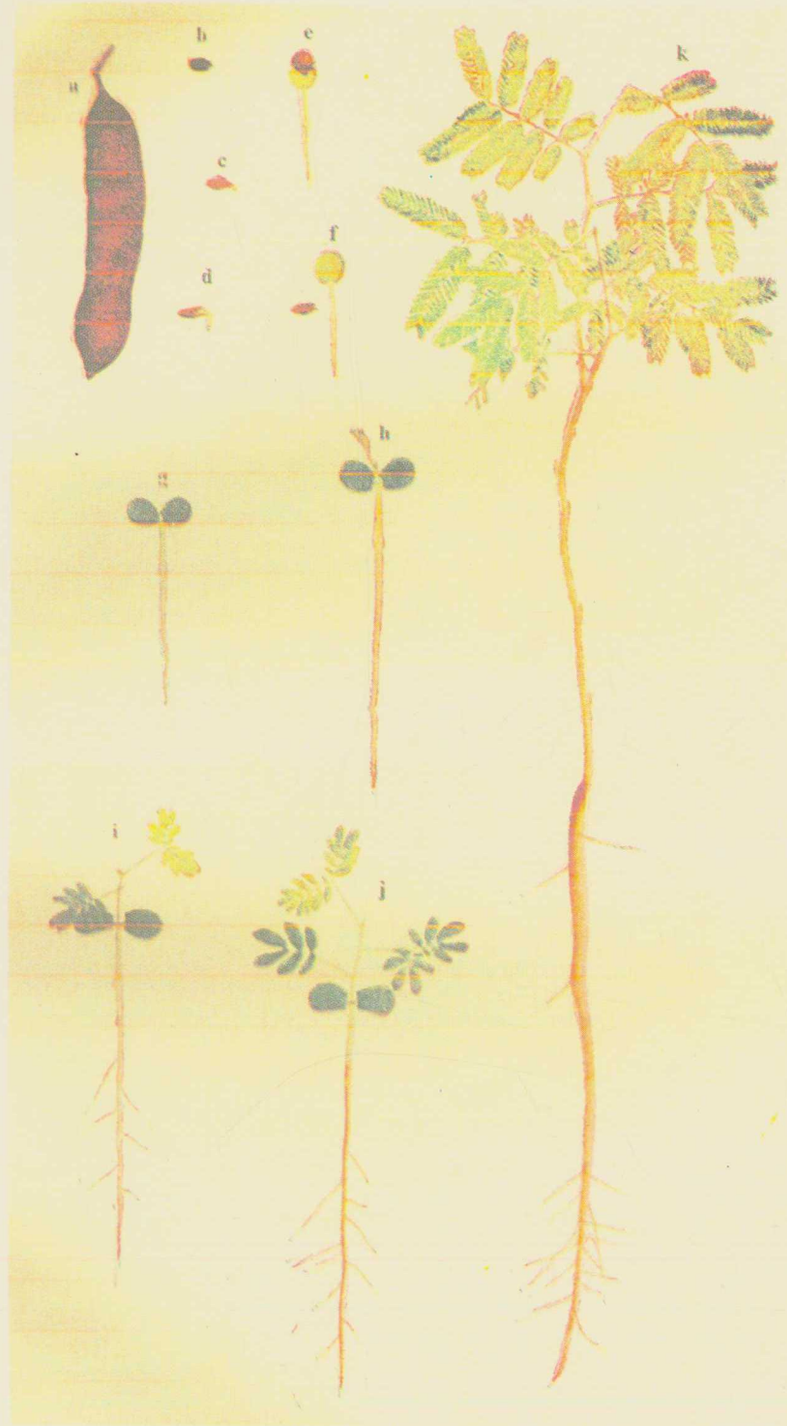
SILVICULTURE AND MANAGEMENT

PHENOLOGY

The tree is leafless for a time during the host season. In Northern India, leaves are shed about February, the new leaves appearing towards the end of April or during May. When leafless, the khair forests have grey or dreary appearance, in strong contrast to the fresh green sissoo crops which by that time have come into new leaf. By June, however, the khair forests have acquired their new delicate green feathery foliage and are a beautiful sight. Flowers appears at the same time as new leaves and add to the beauty of the trees. The tree continues in flower until July or August; sometimes later. The pods develop rapidly, becoming full-sized by September or October and turning from green to reddish green, and then to brown; they begin to ripen by the end of November and continue ripening during December and early January. The pods dehisce not long after ripening and commence falling in January, continuing to fall in the succeeding months. Some pods remain on the tree until the following October, by which time, however, the seed has become so damaged by insects as to be useless.

The phenology and seasonal progress of height growth of *Acacia catechu* of local and Myanmar (Burma) origin have been studied in detail at the Forest Research Institute, Dehradun over a period of several years (Krishnaswamy & Mathauda : 1954). The average dates of occurrence of the various phytophases and the range over which they may usually be seen in this locality are given in Table 4.1.

Acacia catechu puts on new leaves during summer and the leafing normally lasts for about 2 month in case of trees from seed of Burma origin, the period lasts about



Pl.4.1 *Acacia catechu* seedling a. fruit b. seed c-g Germination stages. h-j Early development of Seedling first season; k - seedling towards end of second season.

Table 4.1. Phenological Behaviour of Khair at Dehra Dun

Phenomenon	Date of occurrence			
	Acacia catechu (Myanmar origin)		Acacia catechu (local)	
	Range in which noted to occur	Average	Range in which noted to occur	Average
Begining of new leafing	20th april to 27th May	14th May	15th April to 4th June	15th May
Completion of new leafing	7th July to Ist August	21st July	28th May to 20th July	13th June
Begining of opeining of flowers	16th June to 20th August	6th July	8th June to 21st July	22nd June
Maximum flowering	4th July to 8th September	22nd July	18th June to 31st July	8th July
End of flowering	30th June to 31st September	24th Sept.	10th July to 18th August	Ist August
First ripe fruit	"	"	20th Oct. to 13th Dec.	17th November
Most fruits ripe	"	"	25th Nov. 10 31st January	23rd December
Beginning of falling of fruits of seeds	"	"	20th Dec. to 9th April	8th February
Most fruits or seeds fallen	"	"	14th March to 28th May	13th April
All good fruits or seeds fallen	"	"	18th March to 6th June	9th May
Commencement of leaf fall	12th Jan. to 11th April	5th March	11th Feb. to 6th April	9th March
Completion of leaf fall	5th April to 19th May	3rd May	17th April to 20th May	6th May

a week longer. The average leafless period is 9 days in case of trees from seed of local origin and 11 days from those of Myanmar origin.

SITE FACTORS

Climate

In the natural habitat of khair, the absolute maximum shade temperature varies from 40.0° to 50.0°C and the absolute minimum from 2.5° to 7.5°C. The mean daily maximum temperature in May which is generally the hottest month in the hot weather varies from 37.5° to 43.5°C. The mean daily minimum temperature in January which is the coldest month of the year varies from 1.0 to 2.1°C. *Acacia catechu* is essentially a tree of comparatively dry regions though in its alluvial form, it extends into regions of heavy rainfall as in the Eastern sub-Himalayan tract, where it found in places with a rainfall as high as 3,800 mm. Away from riverain tracts it occurs in localities where the normal rainfall varies from 500 to 2160 mm. Khair develops to its maximum size in localities with heavy rainfall but it is decidedly xerophilous and grows in dry situation where few other species survive.

Topography

It is found on flat or gently undulating ground and ravine country as well as in hilly region but seldom extends in areas above 1200 m in elevation above the sea level.

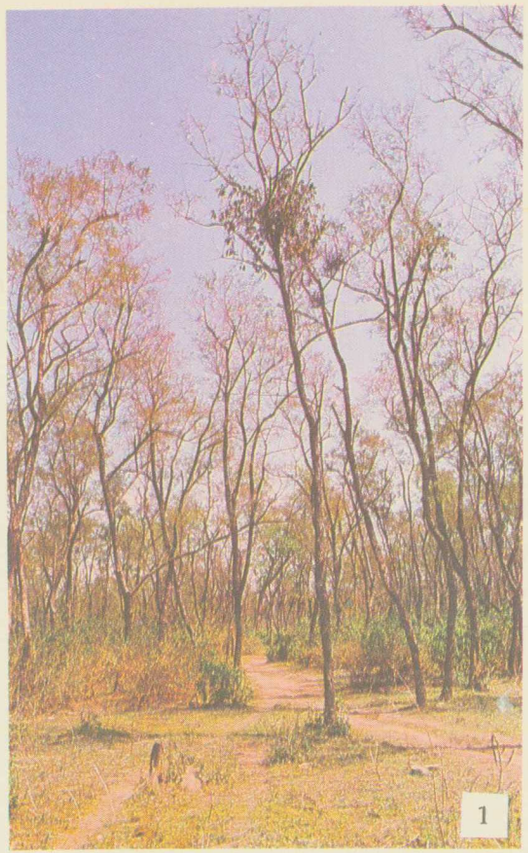
Geology and Soil

Khair occurs on a variety of geological formations and soil, though it undoubtedly thrives best on porous alluvium composed of sand and shingle and on well drained sandstone. It is known to occur on granite, gneiss, schist, quartzite, shale, basalt, trap, limestone, conglomerate and laterite. As regards soil it is common on sandy and gravelly alluvium and on loam or gravel with varying proportions of sand and clay. It grows also on black cotton soil. It is frequent on arid, shallow, stony soil and is capable of existing even in rocky outcrops. It grows in poor shallow soils, composed of murram or kankar where few other species can survive; this adaptability is also seen in parts of the sub-Himalayan tract, where it grows pure, though in stuned form, on poor hard soil composed largely of calcareous nodules, where hardly any other species can exist. On stiff clay where the drainage is bad, it becomes stunted and tends to die off early.

GERMINATION AND SEEDLING STAGES

Epigeous; the radicle emerges first and curves downwards, the hypocotyl then elongates with or without arching and raises above ground and cotyledons enveloped by the testa. The cotyledons expand turning from yellow to pale green and the testa falls to the ground.

The seedling : Roots Primary, long, wiry, thickening considerably after a few months, terete, tapering, whitish or pale brown becoming darker brown; lateral roots few to numerous short, fibrous or wiry, distributed down main root; nodules present.



Pl.4.2 Fig.1. A tree of khair with *Loranthus* attack. 2. Khair plantations in Mohand Range, Dehra Dun.

Hypocotyl : distinct from root, 13-20 mm long, terete, expanded in a ring at the base, white becoming green glabrous or sparsely pubescent in upper part. Cotyledons very shortly petiolate, plano-convex, somewhat fleshy, 8 to 10 mm in diameter, orbicular, entire base sagittate, glabrous, yellow becoming green, obscurely 3-veined.

Stem : erect, somewhat zig-zag at the nodes, thin, delicate at first, becoming wiry, green or reddish, young parts pubescent, elsewhere glabrous or nearly so.

Leaves : alternate. Stipules minute, subulate, caducous. First leaf once paripinnate with three to four pairs of opposite leaflets, 5 to 6 mm by 2.5 mm, rachis pubeso; pairs of leaves bipinnate at first with one pair, then with two pairs of pinnae, each pinna at first with 3-5 subsequent leaflets, the number increasing with succeeding leaves, leaflets 5 to 10 mm by 2.5 to 5 mm ; the number of pinnae increases in subsequent leaves.

Under favourable conditions, the growth of the seedling is rapid from the commencement, plants regularly weeded and watered attaining a height of 91 cm or more in three months from germination. Branching takes place at an early age and general habit is more or less straggling. Record of height measurements of seedlings made at Dehradun show that height growth commences in June normally when the rain falls, is vigorous during the rains and comes to a complete stop in October. The average height attained by khair seedlings in these experiments was 127 cm in one growing season, 200 cm in two growing seasons and 203 cm in three growing seasons (Howard, 1924). Under natural conditions the growth of seedlings may be extremely slow, particularly if they are hampered by weeds or are subject to damage by grazing. Thus a plot of natural seedlings 19 sq. m. in area on sand and shingle among scattered tufts of grass in a dry river bed in the Siwaliks was kept under observation by the Central Silviculturist for about 4 1/2 years. The Table 4.2 shows the number of seedlings counted and their maximum height at different stages.

Table 4.2. Showing number of seedlings counted and their maximum height at different stages.

Date of observation	Number of seedlings present	Maximum height of seedling in cm.
December 11, 1909 (End of Ist Season)	201	15.2
December 28, 1911 (End of 2nd Season)	Not counted	30.5
December 19, 1913 (End of 4th Season)	74	27.9
April 14, 1915 (Begining of 6th Season)	24	25.4

These results show a steady dimination in number of seedlings and no progress in their growth, this being due mainly to damage by grazing; nearly all the survivers were found in the clumps of grass, where they received a certain amount of protection.

Irrigation and weeding have a very beneficial effect on the development of seedlings and it has been demonstrated in various experimental plots at the Forest Research Institute, Dehradun. In most of the unweeded plots, the seedlings were all killed out by supression or had damped off before the end of the third season. One of the commonest forms of mortality in the case of seedlings in a heavy growth of weeds is the damping off to which they are subject to during the rains. In tall open grass, however, where they are not subjected to such a degree of damp, they are capable of

making their way up successfully, though their development is comparatively slow during the process.

The seasonal height growth of *Acacia catechu* was investigated at Dehradun in the Forest Research Institute. The trend of seasonal height growth was compared with the daily mean temperature. It was found that the height growth curve was a simple one with a primary and a secondary maximum. The primary maximum occurred before the monsoon and secondary one after the break of the monsoon. From the shape of the height growth curves, it is to be presumed that the species can work with very little moisture and that the temperature becomes the predominating factor for determining height growth when the temperature curve is exceptionally smooth, the growth curve is likewise smooth.

SILVICULTURAL CHARACTERS

Acacia catechu is a strong light demander. The tree coppices well up to a moderate size and produces root suckers, particularly where the roots have been exposed. Coppice shoots, however, require complete light for their development and under shade, they are not produced at all, the stools dying off. POWELL from Thayetmyo, Myanmar reported that very few coppice shoots are sent up by stumps from trees cut during the rains. Enumerations carried out in an experimental plot laid out in Palamau division of Bihar in 1935 regarding the copicing power of *Acacia catechu* gave the following indications :

1. Stool mortality is high (38%) . It is roughly 20% upto a diameter of 20 cm. Above 20 cm diameter the stool mortality rises rapidly to about 50% at 36 cm diameter. Stool mortality is much higher with low coppicing than with high coppicing.
2. Low coppicing gave the smallest diameter and height of the best shoot per stool and hence the smallest volume per stool.

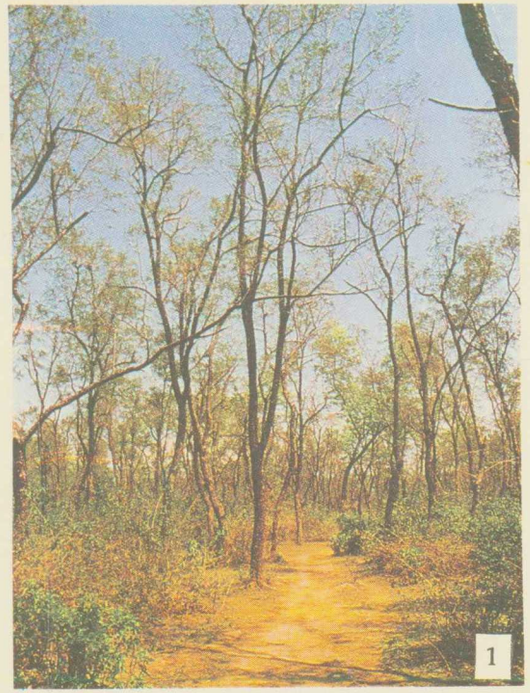
Two experimental plots laid out in Palamau Forest Division, Bihar in 1953-54, indicated that stump mortality is 50% under shade whereas it is only 25-30% in the open in all diameter classes upto 40 cm diameter at breast height.

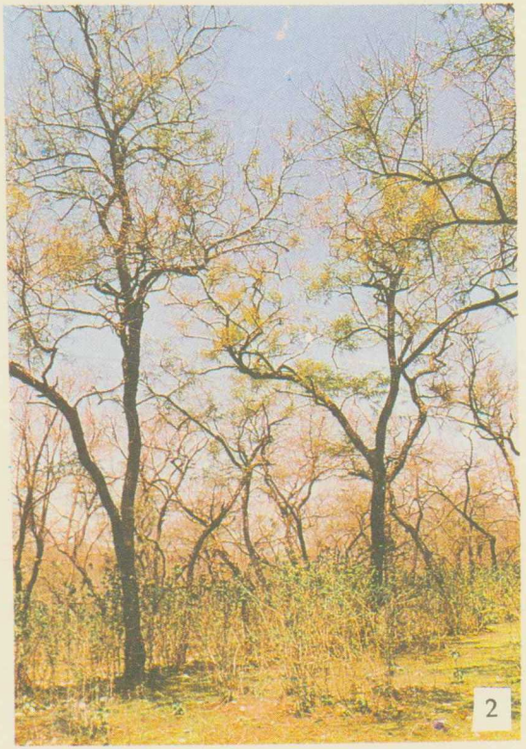
Enumerations carried out in an experimental plot in Ramnagar forest division, U.P., part of which was fenced by a game proof fence, part by a cattle proof fence and part unfenced gave the results as indicated in Table 4.3.

Table 4.3. Coppicing of *Acacia catechu* trees of diferent diameter classes under various kinds of fencing

Kind of fence used	Number of stumps of *Acacia catechu* which coppiced, diameter classwis					
	0-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60 cm and over
Game proof fence	--	8	28	23	20	6
Cattle proof fence	2	1	5	7	5	3
Unfenced	--	2	4	11	2	5
TOTAL	2	11	37	41	27	14

(Contd.)





Pl.4.3 Fig.1. Khair mixed with *Dalbergia sissoo*. 2. Khair trees growing on farm bunds.

Kind of fence	Number of stumps of *Acacia catechu* which coppiced, diameter classwise					
	0-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	60 cm and over
Game proof fence	--	1	7	6	2	2
Cattle proof fence	--	--	3	2	3	4
Unfenced	--	--	1	4	1	2
TOTAL	1	11	12	6	8	

The percentage of success was 77.7 %. In the unfenced area the coppice shoots were badly browsed (Khanna, 1953).

The effect of light on the development of seedlings has been studied at Dehradun in the case of plants grown in plots under varying degrees of shade. These tests proved the seedlings to be strongly light demanding and liable to be killed out in one season where the shade is dense. In infancy, i.e., till the seedlings are established, however, some side shade is required.

Although it stands fire considerably, growth is inhibited and many young seedlings die out or die back by the annual firing of grasslands. Protection from fire helps seedlings in growing through the grass and establishing themselves. Although decidedly xerophilous in character, and capable of growing in dry situations where almost every other species fails to survive, it may suffer severely in years of abnormal drought as in 1899-1900 and subsequently in the Indian Peninsula and in 1914-15 in Palamau, Bihar. In the abnormal drought of 1907 and 1908 in Avadh, it was unaffected on the low alluvial lands where it grows. The seedlings are apt to suffer from drought during long periods of dry weather. In the dry regions, the seedlings sometimes die back for a few years in succession, eventually shooting up after the root has established itself. Within its habitat, it is decidedly one of the most frost-hardy species though young seedlings are somewhat tender during the first few years, in the abnormal frost of 1905 in northern India it stood the frost better than most species, though young coppice growth was killed back. By paired comparison, Sinha (1967) has concluded that in Palamau (Bihar), Khair is more frost-hardy than, amongst others *Buchanania lanzan, Emblica officinalis, Lagerstroemia parviflora, Cassia fistula, Ziziphus mauritiana, Ficus benghalensis, Butea monosperma, Diospyros melanoxylon, Terminalia alata* var. *alata, Shorea robusta* and *Syzyium cumini*. It is however, less frost-hardy than *Phoenix acaulis*. It is often found thriving in frosty grasslands where tender species succumb (Joshi, 1983).

NATURAL REPRODUCTION

Under natural conditions, the seed is disseminated by wind. The seeds adhere to the light pod valves after the pods dehisce and are often blown to a considerble distance from the trees. In alluvial tracts, dissemination of the seed is further effected by water. Though the seed itself is rather heavy the pod with seeds get washed down and the seeds rubbed off among the sand and boulders of newly thrown up islands and banks (Gamble, 1922). Germination takes place in the beginning of the rainy season and the early development of the seedling is greatly favoured on loose soil free from

weeds. Thus on alluvial sand or gravel, countless number of small seedlings may be found in the early part of the rainy season not only in the open but also under comparatively dense cover. In the latter case they die rapidly owing mainly to shade and to damping off and by the end of the season, most of the seedlings disappear. In the open, a fair proportion survives provided the seedlings are protected from grazing. The adverse effect of grazing has already been alluded to. The cattle are very fond of young shoots and closure of areas under regeneration has strikingly beneficial results. Frequently, there is a high mortality from drought, particularly if the soil is stiff or shallow and the roots have difficulty in penetrating it. The seed germinates readily with heavy rain and although germination takes place ordinarily at the commencement of the monsoon, it may begin earlier in the season in case of early heavy showers of rain; when this happens the seedlings generally die off or the germinating seed perishes in the ensuring spell or dry wheather. Such mortality is particularly marked in the case of seeds germinating on the surface of the ground. In the alluvial riverain situations, the tufts of grass which frequently appear on new ground, provided they are not too dense act as a useful protection from drought in the early stages. In wet and sodden grass, however, the seedlings damp off. Khair seed is very delicate and is at once killed by the slightest damage from fire. As the seed falls in January and February, that is to say, just before the fire season commences, fires must be rigidly kept out from the areas under natural regeneration. The slightest carelessness in this respect may jeopardise a whole year's natural regeneration.

The freedom with which natural reproduction of khair springs up in alluvial riverain tracts is remarkable. The chief factors favouring it in such localities are the new loose soil free from heavy weeds and the abundance of light while the soil moisture obtained by percolation no doubt also assists the development of the seedlings. As the crops become older and elevated above the river bed through changes in the course of the river, the conditions for natural regneration change. The ground becomes harder and a dense undergrowth of *Adhatoda vasica* or other plants frequently makes its appearnace. Under such conditions, natural reproduction is no longer possible and although it continues to take place where new alluvium is thrown up, it ceases under the old crops.

ARITIFICIAL REGENERATION

There is generally little difficulty in obtaining regeneration of this species by artificial means. Numerous experiments were carried out at the Forest Research Institute, Dehradun and Clutterbuckgunj, U.P. to ascertain the best method of regenerating khair artificially. These experiments have shown that transplanting cannot be relied upon as the seed cannot withstand the shock of transplanting but direct sowings if carried out properly are highly successful. Khair can also be easily propagated by root and shoot cutting (stumps). Experiments carried out at the Forest Research Intitute, Dehradun to compare the results of direct sowing, planting entire transplants and stumps indicate that the stumps are significantly superior in height development to sowings and entire transplants but inferior in survivals. Stump planting, however, has one great advantage as it reduces the cost of weeding. Entire planting was tried under different conditions both in the first and second season and moderate success was attained only by planting out young plants about 6 weeks old early

in the first rainy season, care being taken to avoid injury to the root system. Pruning of the roots and stem invariably resulted in death of the seedlings. For all practical purposes, winter entire transplants are a failure. Height development in the first year is best from stumps, entire plants come second and direct sowing last. These differences get evened out later on. It is not possible to propagate this species through the use of root sections.

As a rule the tree seeds well almost every year and produces an abundant crop of pods. The tree produces fertile seed at an earlly age. Poor seed years are very rare and are due to abnormal factors such as severe drought, etc.

The pods turn reddish black on ripening and may be collected from the tree in December or early January. As pods begin to dry, insects begin to attack the seed. Pods should, therefore, be collected at the stage when they are just ripe but have not yet begun to dry. After collection they should be spread in the sun for a few days for drying. The seed clings tenaciously to the pod-valves and in order to detach it, it is necessary to heap the pods on a large cloth and beat it well with sticks, after the seeds can be separated by shaking and winnowing in a flat basket.

Khair seed is subject to insect attack, even when carefully stored and does not store well as most leguminous seeds. It is hardly worth storing for more than 6 to 8 months (Dent, 1948). Tests carried out in nursery beds at Clutterbuckgunj showed a germination per cent of 5.1 to 17.0 after one year's storage and 9.4 after 2 years storage in gunny bags.

Pods Collection

It is necessary to collect pods from healthy mature trees. In Thailand, *A. catechu* normally begins to flower and produce pods at the age of 5-7 years old. It usually flowers in August and September, and a pod becomes mature in the following january and February. It is best to collect the mature pods in February. the pods must be picked by hand directly from the trees before the pods to open and scatter their seeds. Pods laying on the ground might already be damaged by *Bruchus bilincatopygus* Pic. or other insects.

Seed Extraction

The collected pods are spread out in a thin layer on canvas, on a tight floor, or on trays, and exposed to the sun or kept in an airy loft, until the pulpy exterior over the seeds drier thoroughly. When it is dried, it is ready to be broken up and placed into water. It is preferable to remove the pulpyu covering from the seeds. Thorough mashing and stirring in the water causes the seeds to become detached and sink to the bottom, and the pulp rises to the surface. After separation, the seeds should be spread out in a thin layer to dry. It is best to dry tem slowly in lthe shade or in an airy loft. When thoroughly dry, they are ready for storage or seeding. There are approximately 18,000 seeds/kg, 35% of which can germinate in moist sand.

Seed Storage

The length of storage for *A. catechu* seeds can be increased by keeping the seeds in dry cold storage. If the seeds are found to be infested by insects at a time of storage, the insects should be destroyed. The best method of destroying the insects is to subject the infected seed to fumes of carbon bisulphide or mix the seeds with insecticide.

Seeding

There is need for nursery - grown stocks in the naturally regenerating *A. catechu* stands, because such a regeneration sometimes fails and artificial planting must be employed to complete the stand. Planting stock should be grown in a nursery under conditions similar to the planting site.

Temporary nurseries are usually small and are increasede or decreased in number according to the demand for planting materials. Wherever possible, they should be partially surrounded by high forest to break the forece of the wind. They are usually locateed on recently felled areas where there is an abundance of organic matter in the soil and are abandoned before the soil deteriorates under successive cropping. Manuring is not necessary. The most important factors influencing selection of a nursery site are soils, water supply, slopes, accessibility and an adequate labour supply.

A nursery should be established on a site that is well drained, free from rocks and other debris, and having good soil. It is necessary to select the best soil for seed beds. Heavy, lumpy clay soils are leass suitable for seedlings. Seed beds are normally l to 1.2 m wide with 0.5 m of a gap for a path land the same length as a compartment or, when the compartment is large, half of its length. Wooden curbs are occasionally placed around seed beds. Curbs check washing of soil in raised beds and permit development of a full stand of seedlings long the borders. it also prevents damage to seedlings on the edge of a seed bed kwhen labourers are weeding.

Seed beds may be sown broadcast in early summer- in the beginning of March in Thailand. Normally, the germination percentage of A. catechu is about 35%. This may be increased to about 70% by soaking the seeds in boiling water and laying them in moist sand. A 30-second boiling time should probably be used instead of a momentary exposure to boiling water (Larsen, 1964).

In broadcast seeding, the seeds should be scattered over the seed beds as evenly as possible, usually by hand and covered by soil or sand. The thickness of soil covering is about 0.5cm. Immediately after the sowing, the seed beds should lbe watered thoroughly and after that kept in a moist condition Boiling water should lbe applied to the seed beds shortly after seeding to destroy the germinating weeds and insects on the surface soil. It also hastens the germination of catechu seeds. Covering with mulch to keep surface soil adequately and uniformly moist is acceptable.

The germination of *A. catechu* begings 5-7 days after the seeds have been sown. Seedlings should be prtected from injuries from rodents, insects and fungi. Once the germinmation begins, it is important to control the moisture condition of the soil, not too moist but never dried out. The seed beds can still be covered to protect young seedlings

from wind injury And, the cover should be gradually removed according to the growth of seedlings. They need to get fresh air and sufficient light. If not, they grow tall and spindly because of a lack of light, and their weak and succulent tissues will be exposed to danger of diseases. Whenever seedlings are found too dense, they should be thinned to desired density.

Transplanting

When seedlings have sufficiently grown, they are transferred from the seed beds to plastic bags about 10cm x 15 cm in size by lifting them carefully from the seed beds, taking care not to injure the roots. The roots are commonly trimmed by experienced workers with a single stroke of a cleaver. Only rigorous and sturdy seedlings should be transferred within a week. Watering and caring for the transferred seedlings is very important. Fertilizer with urea may be applied for producing healthy and fast growing stocks.

Planting.

When the stocks or seedlings are 6 months old or 30-50cm in height, they can be transferred to a planting site that has been prepared during summer. It may be plowed or simply weeded. Small trees are easily destroyed by fire and also seriously damaged or killed by rodents and livestock. The fire problem is most serious in many forest plantations. Therefore, it should be prevented by a fire protection line or by weeding. Rodents such as rabbits, gophers, ground squirrels, and wood rats or pack rats, often damage young stock, and can even destroy a whole plantation. Rabbit injury can greatly reduce height growth of seedlings and saplings when their density is high. In addition, grazing and browsing animals may be problematical in a plantation. Planting sites should be protected from such dangers by fencing or guarding.

A. catechu planting is usually done at the beginning of the rainy season. A planting hole is bout 50-75 cm in width and depth, and spaced about 4x4 m or 2x4 m apart. Manuring the hole should be practiced. A planting stock must be carefully transplanted into a hole with the soil replaced to the same previous soil level. Then fix the stock with a stake. Watering and caring for the young plant is necessary.

A. catechu can be planted by lusing a shoot cutting when the stock is to big or older than on year. The stock is lifted or dug from seed beds and trimmed with a single stroke of a cleaver, keeping 3-5 buds. The stock can be stored for 7-15 days under conditions that afford adequate air and moisture. To plant, drill a hole in the soil and insert the prepared stock. The root collar level of the inserted stock must be at the level of the soil. Press the soil around the stock. Water the stock about 15 days, and it shoud be growing. The same kind of protection mentioned above for plantations against fire, animal damage, pest and diseases should be provided. Fertilizers may be applied for healthy and fast growing trees. This work can be practiced only in the beginning of the rainy season.

Growth and development

In India it is observed that the annual increment of the heartwood of *A. catechu* does not culminate, but goes on increasing up to the end of life. Still, in reality, the tree

never attains a large size on poor soils, and on good soils it ultimately gets suppressed by other species.

The growth of *A. catechu* has been studied at the Pang-asok Experimental Plantations in Nakhon Ratchasima province in northeast Thailand. The result shows that the annual increment in girth is 2.5-4 cm in an average growing tree as shown in Table 4.4. The trees that coppiced from mature stumps show much faster growth than ordinary ones that started from seedlings. These can grow up to 15 cm in girth and 3 m in height within eight months with 3-4 stems per stump.

Table 4.4. Growth of *Acacia catechu*.

Age	Growth data		Growth equation	
Year	Girth (cm)	Height (m)	Girth (cm) *	Height (m)
1	-	-	4.0	1.38
2	-	-	7.6	2.01
3	-	-	10.9	2.49
4	-	-	14.1	2.91
5	17.3	2.92	17.2	3.27
6	20.5	3.11	20.3	3.61
7	32.6	3.15	23.3	3.92
8	-	-	26.2	4.21
9	23.7	4.84	29.2	4.48
10	19.6	3.93	32.1	4.74
11	28.2	4.63	34.9	4.99
12	32.2	6.55	37.8	5.23
13	57.2	6.15	40.6	5.46
14	62.8	7.74	43.4	5.68
15	-	-	46.1	5.89
16	-	-	48.9	6.10
17	-	-	51.6	6.30
18	-	-	54.4	6.50
19	-	-	57.1	6.69
20	-	-	59.8	6.88
21	58.6	7.52	62.4	7.06
22	67.4	7.57	65.1	7.23
23	77.6	8.89	67.7	7.41
24	78.3	10.26	70.4	7.58
25	82.9	9.44	73.0	7.75
26	81.2	9.18	75.6	7.97
27	78.9	8.79	78.2	8.07
28	66.6	8.39	80.8	8.23
29	65.1	8.85	83.4	8.39
30	88.2	10.69	86.0	8.54

* Girth at 1.30 meters above the ground.

Seed weight and Germinative capacity.

About 40,000 seeds weigh one kg (Anon, 1957). The number of pods is about 4,590 per kg. The Table 4.5 shows the results of weighments of seeds and fruits and germinative capacity in various localities.

Table 4.5. *Acacia catechu*, Seed Weight, Germinative Capacity, Plant Per cent etc.

Place of collection of seed	Month of collection	No. of seeds (per kg)	No. of pods (per kg)	Germinative capacity	Plant percent	Commencement & completion of germination (No. of days after sowing)	Source of information
Not known	--		--	39	20	4-42	Sen Gupta, 1937
Uttar Pradesh	Jan-March	38,810	--	73	45	13-56	Do.
Not Known	Jan-March	38,810	--	--	--	--	Do.
West Bengal	Jan.	38,810	4590	70	--	14	Do.
Punjab	Feb.	27,166	--	--	--	--	Do.
Madhya Pradesh	January	22,935	2434	80	--	--	Communication from State Silviculturist
Uttar Pradesh	--	--	--	22.4 to 70(a)	--	--	Raynor, 1940)
				66.8 to 76(b)			
				50.8 to 65(c)			

Note a) in ordinary nursery beds.
b) in sand boxes.
c) in saw dust.

The seed germinates with moderate rain and requires no special preparation to stimulate germination but it is an advantage to soak it in cold water for 24 hours before sowings. In West Bengal, the pods are soaked in water for one or two days in May and then sown, there being no need to separate the seed.

Nursery technique

Nursery work presents little difficulty provided the basic conditions of complete overhead light, a sandy loam soil, adequate irrigation and drainage are fulfilled. For optimum growth, nursery should be kept free of weeds as these are liable to kill seedlings by suppression. One of the commonest forms of mortality in the case of seedlings in a heavy growth of weeds is the damping off to which they are subject during the rains. Soil working also is beneficial especially in the case of heavier soils. Irrigation is beneficial.

Formation of Stands

(i) Sowings. - Direct sowing gives good results and is very easy. The success of direct sowings depends upon: (1) through initial preparation of the soil and keeping it loose for the first two years after sowing (2) timely and adequate weeding for the first two years, (3) abundance of light from the very begining, (4) successful animal and fire protection and (5) absence of frost and drought in the first few years. In addition, the thinning out of young plants has a marked effect on their development. Irrigation undoubtedly stimulates the growth of plants but is not essential provided regular loosening of the soil is carried out.

The method of sowing necessarily vary under different conditions. In the grassy savannahs of Avadh, line sowings have proved successful in spite of a fairly tall growth of grass in the rains. Mound and ridge sowing have been carried out with varying success. Owing to their high cost, however, they are hardly justified except on very stiff soil where the drainage is bad. In areas flooded for long periods in the monsoon, khair should be sown on mounds at least 61 to 76 cm in height so that the seedlings do not remain submerged in water for a long period; a few weeks' submersion is not fatal. Broadcast sowing has also been frequently tried often success : where suppression from weeds is to be feared, however, it cannot be compared with line sowings. The method which has succeeded best and is also very cheap is that of line-sowings with or without the raising of agricultural crops and is being adopted in several parts of India. In Maharashtra, line sowings in conjunction with field crops have proved successful.

In Uttar Pradesh, large areas of miscellaneous forests of little value have been converted into plantations of valuable species such as *Acacia catechu* by line sowings with rains weeding and fencing. The usual procedure adopted is given below although the operational details vary considerably from place to place.

The annual crop is clear felled, the timber and firewood extracted and the area divided up into plots varying in size from 0.4 to 1.6 ha. and distributed among cultivators. The distribution of the area among the cultivators is so timed that they get possession of the land to enable them to sow their kharif,i.e., rains' crop in it. The

cultivators then prepare the land for sowing, by burning the slash, uprooting the stumps if necessary and working the soil by hoeing or ploughing. In many places unrestricted cultivation with any field crop is allowed in the first season. In the second season, the ground is prepared for the sowing of the selected tree crop in lines which may be kept 4.6 to 7.6 metres apart and the sowing of this and the field crop is done at the appropriate time. Both the forest crop and the agricultural crop grow up simultaneously and the cultivators undertake to keep the seedlings well weeded and to prevent the field crop from shading and suppressing the seedlings. Protection of the field crop from wild animals and its irrigations by cultivators also benefit the seedlings. Cultivators may continue to take out field crops and tend the seedlings alongwith them from 1 to 3 years after the introduction of the tree crop, depending upon the fertility of the soil and the rate of growth of the seedlings. In the meanwhile they also get each year freshly cleared areas for sustained working. When the seedlings render taking out of field crop from an area uneconomic, that area is not longer cultivated and left for normal protection by forest staff. This system depends on the cooperative effort between the cultivators and the Forest Deparment to the benefit of both. By operating the method systematically, the Department shifts the cultivators from site to site, ensuring to them adequate area for cultivation, which may comprise of newly cleared plot as well as plantations of first, second and third years. The regeneration areas are dispersed conveniently round a centre at forest village where amenities of water-supply, education and medical aid are departmently provided. This system of cultivation promotes vigorous growth, the thorough working of the soil and the weeding causing the roots to strike deep down from the commencement. A height of 2 to 4 m may be attained in two years and 6 m in four years on deep moist oil.

Plantaions of khair have been extensively raised in many forest divisions of Uttar Pradesh for more that 50 years now. Prior to 1955, the plantations in Landsdowne, Bijnor, Ramnagar, Haldwani and Tarai and Bhabar were mostly raised without field crops, while those in Dehradun, Saharanpur, Bahraich and North Gonda were raised alongwith field crops, by taungya technique. After 1955 mechanized soil working has come in vogue in many divisions, notably Tarai and Bhabar, Haldwani, Ramnagar and Bahraich and plantations are raised with field crops, though not in accordance with the traditional taungya technique. In these mechanized plantations the annual felling coupes are much larger, several hundred hectares. The standing forest is marked for clear-felling and sold by auction, with a stipulation that all the trees will be felled by uprooting upto 60 cm depth and all the old stumps as well as the surface roots will be dug out by the purchaser. This operation as well as the extraction and removal of all the produce and roots is, under sale-deed to be completed in the cold weather. The area so cleared is given a hot burn and is first fully ploughed, then harrowed and finally ridged by tractors, the last operation consisting of laying out 45 cm high parallel ridges spaced 3-4 m apart centre to centre throughout the area. A system of roads and paths is then laid out, dividing the large coupe area into smaller plots of about 20-30 hectares. These plots are leased out for cultivation for 1-2 years, with the condition that the lessee will also look after, weed and tend the forest plants sown or planted along the ridges, together with his own crop. Khair and other seeds are sown in the ridges in the 3rd week of June. The seed germinates with the out-break of monsoon and seedlings are weeded by the lessee. Three weedings have to be carried out by him in the first year and remains so till the plantation is about 6 years old. On the termination of lease, fire-protection is the most important operation to be looked after by the department. It

is generally carried out by laying out a number of fire lines round the coupe and plots and keeping them clear by cutting and burning the grass in late winter or spring. Sometimes the tall grasses in the intermediate strips between the rigdes are hoed down by tractors to reduce their inflammability. The pressed grass may, after the plantation has become high enough, with all precautions, be control-burnt in cold weather. Special fire-protection measures become necessary in these areas as the cultivated strips, once abandoned, are swamped by tall grasses which dry up and become very inflammable in hot summer.

Mechanised plantations

In the mechanised plantations, the annual felling coupes are of several hundred hectares. The standing forest is marked for clear-felling and sold by auction, with a stipulation that all the trees are felled by uprooting upto 60 cm depth and all the old stumps as well as the surface roots are dug out by the purchaser. This operation as well as the extraction and removal of all the produce and roots is under sale-deed to be completed in the winter season.

The area so cleared is given a hot burn and is first fully ploughed, then harrowed and finally ridges by tractors, the last operation consisting of laying out 45 cm high parallel ridges spaced 3-4 m apart centre to centre throughout the area. A system of roads and paths is then laid out, dividing the large coupe area into smaller plots of about 20-30 hectares. These plots are leased out for cultivation for 1-2 years, with the condition that the lessee will also look after, weed and tend the forest plants sown or planted along the ridges together with his own crop.

Khair and other seeds are sown in the ridges in the 3rd week of June. The seed germinates with the out-break of monsoon and seedling are weeded by the lessee. Three weedings have to be carried out by him in the first year, three in the second year and two in the third year. The area is already fenced in the summer of the first year and remains so till the plantation is about 6 year old.

On the termination of lease the fire - protection work is carried out by the forest department by laying out a number of fire lines round the coupe and plots and keeping them clear by cutting and burning the grass in late winter or spring. Sometimes the tall grasses in intermediate strips between the ridges are hoed down by tractors to reduce their inflammability. The pressed grass may, after the plantation has become high enough, with all precautions, be control burnt in cold weather.

Root and shoot cuttings(Stumps). - Given optimum condition, khair can also be propagated by stumps. In an experiment carried out in Uttar Pradesh, some cuttings attained a height of 4.6 metres in one year and 5.5 metres in 2 years. The stumps should be made from seedlings about 15 months old raised in nurseries from seed sown in April of the previous year and irrgated till the break of the monsoon. Cuttings should be made from well developed seedlings. The root and shoot should be 23 to 31 cm and 2.5 to 5.0 cm respectively. Experiments carried out at the Forest Research Institute, Dehradun indicate that the best size of stumps at the root collar is 10 to 15 mm in diameter. The seedlings under 10 mm in diameter at the root collar do not make good cuttings, while seedlings thicker than 15 mm in diameter at root collar do not produce satisfactory

shoots or fail to produce shoots. Thickness of the seedlings does not appear to have any influence on the height development in the first year. Planting of stumps should be done soon after the break of rains. Delayed planting is not advisable. Under irrigated conditions stumps can be planted during March-April. Stumps can be stored without affectiny the suvival per cent for 3 days and without causing any significant loss in height growth for a period of 9 days.

Entire planting:- In recent years entire planting of container plants has been sucessfully tried, particularly in Gujarat and Rajasthan. It was found that polythene bags of the size 30 x 10 cm of gauge 350 are suitable as containers. In Indonesia bamboo tubes used as containers for entire transplants are reported to have given good results.

Afforestation

On account of its hardness and value of wood for the production of cutch and Katha, khair is an ideal species for the conversion of miscellaneous forests containing inferior species and is being used to a considerable extent for this purpose in Uttar Pradesh. A remarkable feature of some plantations is the sudden appearance of vigorous natural khair sedlings as a result of burning the area and protection with a deer proof fence (Anon(U.P.), 1928-29) Heavy. grass competition in Tarai increases the cost of these plantations. Khair has also played an important part in the afforestion schemes of ravine lands of the drier parts of Uttar Pradesh.

Irrigated patch sowings of khair have proved quite successful in the Punjab on moderately good soil although they fail on bad *kallar* soil.

Afforestation of *phantas* in North Kheri division in U.P. with khair has been tried but proved unsuccessful even with irrigation.

Experiments carried out to investigate the possibility of afforesting usar land with well defined kankar pan or heavy efforescence in Uttar Pradesh indicate that khair is moderately suitable in mild usar if planting is done in deep pits filled with better soil. In experimental plot Nos. 1 and 2, Avadh forest division, Uttar Pradesh, after four years the survivals were 52% and average height 2.6 metres in 122 cm deep pits filled with better soil from elsewhere. (Anon., 1954-55). These experiments also show that it is possible to raise a poor plantation of khair on such soil.

Tending

Repeated weedings are necessary in the first two or three years. Two good weedings are enough but sometimes a third is required in the first rains. One weeding may be necessary in the third year especially round the backward plants. The amount of weeding needed will depend on the site.

Khair seedlings usually come up in a congested crop. In order that seedlings may develop in the healthy and vigorous crop, proper tending and spacing is ncessary. In the early cleanings, plants may be spaced about 80 to 120 cm apart. Early thinnings are very important for the proper development of the crop. All shade, even lateral, must be removed (Anon, 1957). Normally the first thinning should not be delayed beyond the 5th year. If grown pure it requires repeated climber cutting. In taungya plantations of

North Gonda, the first cleaning is done at the age of 3 years. Subsequently thinnings are done at the ages of 5, 10, 15, 20 and 25 years. The first 3 thinnings are mechanical, in which a spacement equal to half to average crop height is aimed at.

In coppice crops, It becomes necessary to reduce the number of the several coppice shoots sprouting from a single stump to one or two within 3-5 years.

Khair trees usually occur mixed with many other trees in the forest though sometimes there are almost pure khair patches mixed with sissoo in riverain areas. The mixed forests are managed under the system, often dictated by the most important species in them.

Several working plans prescribe selection fellings of all or a certain percent of trees over an exploitable diameter, the object of which is to remove mature trees before they depreciate in value. This, however, does not ensure reproduction which can not be obtained in khair under any system not involving complete clear-felling, due to the ecological status of the species. The only system under which complete regeneration can be ensured on a given area appears to be that of clear-fellings with artificial regeneration. This is the system followed in the sub-Himayalan forests, alongwith selection fellings. The plantations may be regarded as compensating the selection fellings in such cases.

In the case of natural riverain forests, owing to unstable condition of much of the land on which they are situated, it is obvious that as long as the land is likely to disappear through erosion, it is not worthwhile undertaking special regeneration operations on it. Nature carries out this herself by throwing up new land and producing new crops to compensate those which are destroyed. In such unstable lands, the only possible course is to utilize all trees as soon as they become marketable and to extract all saleable, dead and fallen trees at frequent intervals. It is quite certain that khair can not be relied upon to regenerate itself in the felling coupes as they are usually covered with dense grass and weed growth. Dependence for future has to be placed on plantations of compensatory nature raised elsewhere.

Data so far collected indicates that the mean annual increment of heartwood does not culminate but goes on increasing up to the death of the tree. A high exploitable diameter would therefore be indicated but for the fact that on poor soils, khair never attains a large size and on good soils it ultimately gets suppressed by other species. In moist forests, the size preferred for katha manufacture is 30 to 35 cm in diameter. As the heartwood of very old trees is not so good for katha either qualitatively or quantitatively. Most working plans prescribe an exploitable diameter of 30cm for bhabar and 35 cm for tarai forests of U.P. and a felling cycle varying from 10-30 years. In Mahakoshal, the exploitable girth is fixed at 38 cm at the base and the felling cycle is 20 years. In dry peninsular forests of Uttar Pradesh worked under selection fellings, the exploitable diameter is as low as 10 cm, as for Mirzapur forests.

In the mixed dry deciduous forests the tree is frequently worked under simple coppice, coppice with standards or coppice-with-reserves systems both in alluvial tracts and in mixed forests. For instance, khair bearing forests of Jhansi district in Bundelkhand forest division are now being worked under the system of coppice-with

reserves, with natural regeneration by coppice supplemented by seedling regeneration on a rotation of 30 years for coppice, the yield regulated entirely by area. Under the previous working plans, however, khair bearing areas were at first allotted to an overlapping khair working circle under selection fillings on 15 years cycle with an exploitable diameter of 10 cm at breast height or 12.5 cm at the base and later to a miscellaneous working circle under coppice-with -standards system with 30 year and 60 year rotations for Coppice and for Standards respectively. The prescriptions for the Coppice-with-Reserves system presently applied, however, do not have the degree of elasticity, which is the chief advantage of this system over Coppice-with-Standard. They still resemble those of the latter system, which preceded the former system in use in these forests, in as much as a rotation for reserves and a numerical limit for them to be retained per unit area are still laid down.

INJURIES AND PROTECTION

Climatic Factors

. **Drought** : The seedlings are apt to suffer from drought during long spells of dry weather. In plantations very often the first sowings fail completely, if after intial showers and germination, there is such a spell. In the dry regions, the seedlings sometimes die back for a few years in succession, eventually shooting up after the root has established itself.

Frost : The tree is frost resistant, though the seedlings are frost tender during the first few years.

Fire : Although it can stand fires, considerable setback in the growth and development of seedlings is caused. The smaller seedlings are burnt down after a fire but new shoots are sent up almost immediately.

Weeds : Weeds hamper the growth of seedlings. In experiments carried out at the Forest Research Institute, Dehradun, in most of the unweeded plots, seedlings were either killed out by suppression or had damped off before the end of the third season. One of the commonest forms of mortality by heavy weed growth is the damping off to which they are subject during the rains.

Climbers : In the mixed forests, *Acacia catechu* is subject to the usual damage from climbers. In the sub-Himayalan alluvial forests, a very characteristic climber is *Dregea volubilis* which does great damage Other climbers in these forests are *Cryptolepis buchanani* and *Vallaris solanacea* which does great damage.

Parasitic plants *Cuscuta* was reported to have attacked khair plantations in Bahalpali reserve forest in West Sambalpur division and killed them outrigtht. *Macrosolen cochinchinensis* has also been recorded on the tree.

Animals

Domestic and wild animals. : The luscious young plants are badly browsed by deer during the first year; the damage is less when the plants become larger. Pigs do considerable damage by trampling. Khair is very much liked by wild elephants and

suffers much in elephant infested localities (De, 1940). Where wild life is abundant, its exclusion is absolutely essential and a game proof fence is indispensable to the success of a khair plantation. Seedlings are also subject to damage from grazing by domestic animals.

Rats do much injury to the seedlings by gnawing the taproots. The power of recovery, however, is good, numerous cases having been observed of new shoots being set up from the portions of the taproots left in the ground after this form of damage. Rats also devour seed sown in plantations. Porcupine damage is noteworthy in nursery beds; they are also destructive to the larger trees, gnawing the bark off round their bases and often providing centres for fungal infection or even killing them out-right . They may kill the plants even with deer proof fencing. It is reported that smearing of lime is efficacious in keeping off porcupines. An American plan for dealing with porcupines is to soak small boards in brine and strychnine and nail them to the bases of trees, the porcupines have a partiality for salt and gnaw the boards, dying of strychnine poisoning.

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5

GROWTH STATISTICS

Acacia catechu Willd., known as Khair in Hindi,is a moderate-sized deciduous tree with yellowish white sapwood and dark or light red heartwood. The heartwood is very hard and durable and is used to produce cutch and katha. The tree is mostly found in the sandy alluvial beds of rivers and streams which may or may not be dry for a considerable portion of the year. If grown in plantations for maximum volume production for use as fuel, then crop can be harvested at short rotation of 10 to 15 years. But the situation becomes different when the object of management is to meet demands of katha industry. Katha is extracted from heartwood and period of harvest will thus be governed by its optimisation.

Some attempts were made in collecting data from Morni Pinjore Division of Haryana to prepare volume tables applicable for that locality only.

Methodology

Single tree data was collected as per standard practice laid down in the silviculture code Vol. III. While performing the regression analysis we have made certain assumption about the error, the usual assumption are that the errors are independent, have zero mean, a constant variance and follow a normal distribution. To prepare the volume tables the method of stepwise regression was tried and best fi t equation was slected for volume calculations. On the basis of slected equations the volume of stem wood(with bark) and stem wood(under bark) were calculated which are given in tables below.

Volume Table - *Acacia catechu* stem wood (with bark) m^3

$V=-0.003667+4.373288D^2+0.73788*D^2H$

Dbh (OB) (Cm.)	Height (m)																
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
10	.044	.045	.046	.047	.047	.048											
11	.055	.055	.056	.057	.058	.059	.060										
12	.066	.067	.068	.069	.070	.071	.072										
13	.078	.079	.080	.081	.083	.084	.085										
14	.091	.092	.094	.095	.097	.098	.099										
15	.105	.106	.108	.110	.111	.113	.115										
16	.120	.122	.123	.125	.127	.129	.131										
17	.136	.138	.140	.142	.144	.146	.148										
18	.152	.155	.157	.160	.162	.164	.167										
19	.170	.173	.176	.178	.181	.184	.186										
20	.189	.192	.195	.198	.201	.204	.207										
21	.209	.212	.215	.218	.222	.225	.228										
22	.229	.233	.237	.240	.244	.247	.251										
23				.263	.267	.271	.275	.278	.282	.286	.290	.294					
24				.286	.291	.295	.299	.303	.308	.312	.316	.320					
25					.316	.320	.325	.330	.334	.339	.343	.348					
26					.342	.347	.352	.357	.362	.367	.372	.377	.382				
27					369	.374	.380	.385	.390	.396	.401	.407	.412	.449	.455	.461	.466
28					.397	.403	.409	.414	.420	.426	.432	.438	.443	.482	.488	.494	.501
29					.426	.432	.439	.445	.451	.457	.463	.470	.476	.516	.523	.529	.556
30					.456	.463	.470	.476	.483	.490	.496	.503	.509	.551	.558	.566	.573
31					.488	.495	.502	.509	.516	.523	.530	.537	.544	.588	.595	.603	.610
32						.527	.535	.542	.550	.557	.565	.573	.580	.625	.633	.641	.649
33						.561	.569	.577	.585	.593	.601	.609	.617	.664			
34						.596	.604	.613	.621	.630	.638	.647	.655	.704			
35						.631	.641	.650	.659	.668	.677	.686	.695	.745			
36						.668	.678	.687	.697	.707	.716	.726	.735	.787			
37						.706	.716	.726	.736	.747	.757	.767	.777				
38						.745	.756	.766	.777	.788	.798	.809	.820				
39						.785	.796	.807	.819	.830	.841	.852	.864				
40						.826	.838	.850	.861	.873	.885	.897	.909				
41						.868	.880	.893									
42						.911	.924	.937									
43								.982									
44								1.029									

Note: Figures enclosed within in the lines are within the range of observed data.

Total stem wood (Under bark) m^3

$V=-0.013071+3.554539D^2+0.65378D^2H$

Dbh (OB) (Cm.)	Height (m)																
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
10	.044	.045	.046	.047	.047	.048											
10	.026	.027	.028	.028	.029	.030											
11	.035	.035	.036	.037	.038	.039	.039										
12	.044	.045	.046	.047	.048	.048	.049										
13	.054	.055	.056	.057	.058	.059	.060										
14	.064	.066	.067	.068	.069	.071	.072										
15	.076	.077	.079	.080	.082	.083	.085										
16	.088	.090	.091	.093	.095	.096	.098										
17	.101	.103	.105	.107	.109	.110	.112										
18	.115	.117	.119	.121	.123	.125	.128										
19	.129	.132	.134	.136	.139	.141	.144										
20	.145	.147	.150	.153	.155	.158	.160										
21	.161	.164	.167	.170	.173	.175	.178										
22	.178	.181	.184	.187	.191	.194	.197										
23				.206	.210	.213	.216	.220	.223	.227	.230	.234					
24				.226	.229	.233	.237	.241	.244	.248	.252	.256					
25					.250	.254	.258	.262	.266	.270	.274	.279					
26					.271	.276	.280	.285	.289	.294	.298	.302	.307				
27					.294	.298	.303	.308	.313	.318	.322	.327	.332	.363	.368	.373	.378
28					.317	.322	.327	.332	.337	.342	.348	.353	.358	.390	.396	.401	.407
29					.341	.346	.352	.357	.363	.368	.374	.379	.385	.419	.425	.430	.436
30					.366	.372	.377	.383	.389	.395	.401	.407	.413	.448	.454	.460	.466
31					.391	.398	.404	.410	.416	.423	.429	.435	.442	.478	.485	.492	.498
32						.425	.431	.438	.445	.451	.458	.465	.471	.509	.516	.524	.531
33						.452	.459	.467	.474	.481	.488	.495	.502	.541			
34						.481	.489	.496	.504	.511	.519	.526	.534	.575			
35						.510	.518	.526	.534	.542	.551	.559	.567	.609			
36						.541	.549	.558	.566	.595	.583	.592	.600	.644			
37						.572	.581	.590	.599	.608	.617	.626	.635				
38						.604	.613	.623	.632	.642	.651	.661	.670				
39						.637	.647	.657	.667	.677	.687	.697	.707				
40						.671	.681	.692	.702	.713	.723	.733	.744				
41						.705	.716	.727									
42						.741	.752	.764									
43								.801									
44								.840									

Note: Figures enclosed within the lines are within the range of observed data.

In large enumeration it is not possible to measure height of each tree. Relationship between volume and d.b.h. were tried and good results have been obtained.The volume tables for Total wood(Over Bark) and Total wood(Unde Bark) have been given in the table below.

(Total Volume Over bark) V=-1.072253+4.36931D+0.0766831/D
(Total Volume under bark) V=-0.909144+3.640653D+0.0645921/D

DBH (cm)	Volume Over bark (cu.m)	Volume Under bark (cu.m)	DBH Dia. (Cm.)	Volume Over bark (Cu.m)	Volume Under bark (Cu.m)
5	.67987	.56473	28	.42502	.34092
6	.46795	.38583	29	.45927	.36938
7	.32097	.26844	30	.49415	.39836
8	.23583	.18951	31	.52960	.42782
9	.17302	.13620	32	.56556	.45771
10	.13151	.10084	33	.60199	.48800
11	.10549	.07853	34	.63885	.51865
12	.09109	.06600	35	.67610	.54963
13	.08563	.06100	36	.71371	.58091
14	.08719	.06192	37	.75164	.61247
15	.09436	.06757	38	.78988	.64428
16	.10611	.07706	39	.82840	.67633
17	.12161	.08972	40	.86718	.70860
18	.14024	.10502	41	.90620	.74107
19	.16151	.12254	42	.94544	.77372
20	.18502	.14195	43	.98488	.80655
21	.21406	.16297	44	1.02452	.83954
22	.23755	.18540	45	1.06434	.87269
23	.26609	.20904	46	1.10433	.90597
24	.29589	.23375	47	1.14448	.93939
25	.32681	.25939	48	1.18477	.97294
26	.35870	.28586	49	1.22521	1.00660
27	.39147	.31306	50	1.26577	1.04037

The data were collected from 11 sample plots in Utter Pradesh. The distribution of sample plots state and divisionwise is given in table below.

Distribution of sample plots by division

State	Division	Sample plots No.
Uttar Pradesh	Haldwani	36
		37
		43
		44
	Lansdowne	7
	Ramnagar	31
	Rohilkhand	5
		4
	Shiwalik	35
		49
	Tarai and Bhabar	1

The data were analysed using multiple regression technique. Directly measurable characters were used as independent variables. Site index, though not a directly measurable variable, was taken as an independent variable. This was done as it is easy to find out this variable with the help of top height and age, As the relationship of top height to age called site index. The site index using regression equation.

The abreviations and symbols used in the regression equations are :

A	Age, years
BA (M)	Basal area (main crop),m^2/ha
BA (TH)	Basal are (thinning), m^2/ha
CD	Crop diameter, cm
He	Crop height, m
Ht	Top height, m
N	Number of trees per ha
V(M)	Total wood volume (main crop),m^3/ha
V(TH)	Total wood volume (thinning), m^3/ha
SI	Site index

b0,b1 etc Regression coefficients

Volume production

(a) Main Crop- Total wood volume

The regression equation found to fit the data best is

$$\log V = b0 + b1\,(SI) + b2\,[BA(M)/(BA(M) + BA(TH))] + b3\,(1/A)$$

(b) Subsidiary crop- Total wood volume

The equation is:

$$\log V(TH) = b0 + b1(SI) + b2 \log BA(TH) + b3(1/A)$$

Basal area production(Main crop)

The equation is:

$$\log BA = b0 + b1.\ \log A.\ \log SI + b2(A) + b3(SI) + b4 \log N$$

Crop height (Main crop)

The equation is:

$$Hc = -0.390597 + 0.296580\ Ht$$

Crop diameter(Main crop)

This has been derived on the basis of the average crop basal area indicated in the above equation

The estimates of coefficients of determination are provided in table below.

Relevent statistics and estimates of coefficients

Crop characters	Coefficient			
	b0	b1	b2	b3
Basal area (Main Crop)	-6.738557	0.690245	1.257308	0.516114
Total wood (Main crop)	1.998998	0.84084	1.263321	-7.723020
Total wood (thinning)	1.588136	0.035947	1.123153	-9.675661

THINNING

Yield of thinning volume per ha in m^3 by basal area,age and site quality
Site Quality I

Crop age (yrs)	Basal area removed during thinning (m^2/ha)									
	1	2	3	4	5	6	7	8	9	10
15	6.195	13.495	21.279	29.395	37.768	46.350	55.112	64.029	73.085	82.266
20	7.280	15.856	25.002	34.539	44.377	54.461	64.756	75.233	85.874	96.662
25	8.019	17.467	27.543	38.048	48.885	59.994	71.334	82.877	94.598	106.482
30	8.553	18.631	29.378	40.583	52.142	63.991	76.087	88.399	100.902	113.577
35	8.957	19.510	30.763	42.496	54.601	67.009	79.675	92.567	105.659	118.933
40	9.272	20.196	31.845	43.991	56.520	69.365	82.476	95.822	109.374	123.114

THINNING

Yield of thinning volume per ha in m^3 by basal area,age and site quality
Site Quality II

Crop age (yrs)	Basal area removed during thinning (m^2/ha)									
	1	2	3	4	5	6	7	8	9	10
15	5.562	12.115	19.104	26.390	33.907	41.612	49.477	57.483	65.613	73.856
20	6.535	14.235	22.446	31.008	39.840	48.893	58.136	67.542	77.095	86.780
25	7.199	15.682	24.727	34.158	43.887	53.861	64.042	74.404	84.928	95.596
30	7.279	16.726	26.374	36.434	46.812	57.449	68.309	79.362	90.586	101.966
35	8.041	17.515	27.618	38.152	49.019	60.158	71.530	83.104	94.858	106.774
40	8.324	18.131	28.589	39.493	50.742	62.273	74.045	86.026	98.193	110.528

THINNING

Yield of thinning volume per ha in m^3 by basal area,age and site quality
Site Quality III

Crop age (yrs)	Basal area removed during thinning (m^2/ha)									
	1	2	3	4	5	6	7	8	9	10
15	6.195	13.495	21.279	29.395	37.768	46.350	55.112	64.029	73.085	82.266
15	4.993	10.877	17.151	23.692	30.440	37.358	44.419	51.607	58.906	66.306
20	5.867	12.780	20.152	27.838	35.767	43.895	52.192	60.637	69.214	77.909
25	6.463	14.078	22.199	30.666	39.401	48.354	57.495	66.798	76.245	85.823
30	6.894	15.017	23.678	32.709	42.026	51.576	61.326	71.248	81.326	91.542
35	7.219	15.725	24.795	34.252	44.008	54.008	64.217	74.608	85.160	95.858
40	7.473	16.277	25.666	35.456	45.555	55.907	66.475	77.231	88.155	99.229

MAIN CROP

Site Quality I. Yield of volume (m^3/ha)

Crop age (yrs)	BA(M)/[BA(M)+BA (TH)]										
	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
15	50.562	53.859	57.371	61.112	65.096	69.341	73.862	78.678	83.809	89.273	95.094	101.295	107.899	114.955	122.429
20	57.508	61.258	65.252	69.507	74.039	78.866	84.009	89.486	95.321	101.536	108.157	115.209	122.721	130.723	139.247
25	62.125	66.176	70.491	75.087	79.983	85.198	90.754	96.671	102.975	109.689	116.841	124.459	132.575	141.219	150.427
30	65.408	69.673	74.215	79.055	84.209	89.700	95.549	101.779	108.415	115.484	123.014	131.035	139.579	148.680	158.375
35	67.858	72.283	76.996	82.016	87.364	93.060	99.128	105.592	112.477	119.810	127.623	135.944	144.808	154.250	164.308
40	69.756	74.304	79.149	84.310	89.807	95.663	101.900	108.545	115.622	123.161	131.192	139.746	148.858	158.564	168.903
45	71.268	75.915	80.865	86.138	91.754	97.737	104.110	110.898	118.129	125.832	134.037	142.776	152.086	162.002	172.565
50	72.502	77.229	82.265	87.629	93.343	99.429	105.912	112.818	120.174	128.010	136.357	145.248	154.718	164.807	175.553
55	73.527	78.321	83.428	88.868	94.663	100.835	107.410	114.413	121.874	129.820	138.285	147.302	156.706	167.137	178.035
60	74.393	79.243	84.410	89.914	95.777	102.022	108.674	115.760	123.308	131.348	139.913	149.035	158.753	169.104	180.131

MAIN CROP

Yield of volume (m^3/ha)
Site Quality II

Crop age (yrs)	BA(M)/[BA(M)+BA (TH)]										
	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
15	50.562	53.859	57.371	61.112	65.096	69.341	73.862	78.678	83.809	89.273	95.094	101.295	107.899	114.955	122.429
15	39.289	41.851	44.580	47.487	50.583	53.881	57.394	61.137	65.123	69.369	73.893	78.711	83.843	89.310	95.133
20	44.686	47.600	50.704	54.010	57.532	61.283	65.279	69.535	74.069	78.899	84.043	89.523	95.360	101.578	108.201
25	48.274	51.422	54.775	58.346	62.151	66.203	70.520	75.118	80.016	85.233	90.791	96.711	103.017	109.734	116.889
30	50.825	54.139	57.669	61.429	65.4356	9.701	74.246	79.087	84.244	89.737	95.588	101.821	108.460	115.532	123.065
35	52.729	56.167	59.829	63.730	67.886	72.312	77.027	82.050	87.400	93.098	99.169	105.635	112.523	119.860	127.675
40	54.203	57.738	61.502	65.513	69.784	74.334	79.181	84.344	89.844	95.702	101.942	108.589	115.669	123.212	131.245
45	55.379	58.990	62.836	66.933	71.297	75.946	80.898	86.173	91.792	97.777	104.153	110.944	118.178	125.883	134.091
50	56.337	60.011	63.924	68.092	72.532	77.261	82.299	87.665	93.381	99.470	105.956	112.864	120.223	128.062	136.413
55	57.134	60.859	64.828	69.055	73.557	78.354	83.462	88.905	94.701	100.876	107.454	114.460	121.923	129.873	138.342
60	57.807	61.576	65.591	69.868	74.432	79.276	84.445	89.951	95.816	102.064	108.719	115.807	123.359	131.402	139.970

MAIN CROP

Yield of volume (m^3/ha)

Site Quality III

Crop age	BA(M)/[BA(M)+BA (TH)]														
(yrs)	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
15	30.530	32.520	34.641	36.899	39.305	41.868	44.598	47.506	50.604	53.903	57.418	61.162	65.150	69.398	73.923
20	34.723	36.987	39.399	41.968	44.705	47.620	50.725	54.032	57.555	61.308	65.305	69.564	74.099	78.931	84.077
25	37.511	39.957	42.563	45.338	48.294	51.443	54.797	58.370	62.176	66.230	70.549	75.149	80.049	85.268	90.828
30	39.493	42.068	44.811	47.733	50.846	54.161	57.693	61.454	65.461	69.730	74.276	79.119	84.278	89.773	95.627
35	40.973	43.644	46.490	49.521	52.750	56.190	59.854	63.756	67.914	72.342	77.059	82.083	87.435	93.136	99.209
40	42.119	44.865	47.790	50.906	54.226	57.761	61.528	65.539	69.813	74.365	79.214	84.379	89.881	95.741	101.984
45	43.032	45.837	48.827	52.010	55.401	59.014	62.862	66.961	71.327	75.977	80.931	86.209	91.830	97.817	104.195
50	43.777	46.631	49.672	52.911	56.361	60.035	63.950	68.120	72.561	77.293	82.332	87.701	93.419	99.511	105.999
55	44.396	47.291	50.374	53.659	57.157	60.884	64.854	69.083	73.587	78.386	83.497	88.941	94.740	100.918	107.498
60	44.918	47.847	50.967	54.290	57.830	61.601	65.618	69.896	74.454	79.308	84.479	89.988	95.855	102.106	108.763

MAIN CROP

Basal area(m^2/ha) by number of stems, age and site quality

Site Quality I

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													7.1	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8
15									8.1	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.6				
20						8.6	9.0	9.5	9.9	10.3	10.7	11.1									
25						10.0	10.5	11.1	11.6	12.1											
30				9.9	10.6	11.3	11.9	12.5	13.1	13.7											
35				11.1	11.8	12.6	14.3	14.0													
40	9.1	10.2	11.2	12.1	13.0	13.8	14.6														
45	9.9	11.1	12.1	13.1																	
50	10.6	11.9	13.1	14.1																	
55	11.3	12.7																			
60	12.0	13.5																			

MAIN CROP

Basal area (m^2/ha) by number of stems,age and Site Quality

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													6.1	6.2	6.4	6.6	6.8	7.0	7.1	7.3	7.5
15									6.9	7.2	7.5	7.7	8.0	8.3	8.5	8.8	9.0				
20						7.3	7.7	8.0	8.4	8.8	9.1	9.4									
25						8.5	8.9	9.4	9.8	10.2											
30				8.4	9.0	9.6	10.1	10.6	11.1	11.6											
35				9.4	10.0	10.7	11.3	11.8													
40	7.7	8.6	9.5	10.3	11.0	11.7	12.4														
45	8.4	9.4	10.3	11.2																	
50	9.0	10.1	11.1	12.0																	
55	9.6	10.8																			
60	10.2	11.4																			

MAIN CROP

Basal area (m^2/ha) by number of stems,age and site quality

Site Quality III

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													5.0	5.2	5.3	5.5	5.6	5.8	5.9	6.0	6.2
15									5.7	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4				
20						6.0	6.3	6.7	7.0	7.3	7.5	7.8									
25						7.0	7.4	7.8	8.1	8.5											
30				7.0	7.5	7.9	8.4	8.8	9.2	9.6											
35				7.8	8.3	8.8	9.3	9.8													
40	6.4	7.2	7.9	8.5	9.1	9.7	10.2														
45	6.9	7.8	8.5	9.2																	
50	7.4	8.3	9.2	9.9																	
55	7.9	8.9																			
60	8.4	9.5																			

MAIN CROP

Crop diameter(cm) by number of stems,age and site quality

Site Quality I

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													15.1	14.8	14.6	14.5	14.3	14.1	13.9	13.8	13.7
15									18.6	18.2	17.9	17.6	17.3	17.1	16.8	16.6	16.4				
20						22.0	21.4	21.0	20.5	20.1	19.8	19.4									
25						23.8	23.2	22.6	22.2	21.7											
30				26.9	26.0	25.3	24.7	24.1	23.6	23.1											
35				28.4	27.5	26.7	27.0	25.4													
40	34.0	32.2	30.8	29.7	28.7	27.9	27.2														
45	35.4	33.5	32.1	30.9																	
50	36.7	34.8	33.3	32.1																	
55	37.9	36.0																			
60	39.1	37.0																			

MAIN CROP

Crop diameter (cm) by number of stems,age and site quality

Site Quality II

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													13.9	13.7	13.5	13.3	13.1	13.0	12.8	12.7	12.6
15									17.1	16.8	16.5	16.2	16.0	15.7	15.5	15.3	15.1				
20						20.3	19.8	19.3	18.9	18.5	18.2	17.9									
25						21.9	21.3	20.8	20.4	20.0											
30				24.8	24.0	23.3	22.7	22.2	21.7	21.3											
35				26.1	25.3	24.6	24.0	23.4													
40	31.3	29.7	28.4	27.4	26.5	25.7	25.1														
45	32.6	30.9	29.6	28.5																	
50	33.8	32.0	30.7	29.5																	
55	35.0	33.1																			
60	36.0	34.1																			

MAIN CROP

Crop diameter (cm) by number of stems,age and site quality

Site Quality III

Crop age	Number of stems per hectare																				
(yrs)	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
10													12.6	12.4	12.3	12.1	12.0	11.8	11.7	11.6	11.4
15									15.6	15.3	15.0	14.8	14.5	14.3	14.1	13.9	13.8				
20						18.4	18.0	17.6	17.2	16.9	16.6	16.3									
25						19.9	19.4	19.0	18.6	18.2											
30				22.5	21.8	21.2	20.7	20.2	19.8	19.4											
35				23.8	23.0	22.4	21.8	21.3													
40	28.5	27.0	25.8	24.9	24.1	23.4	22.8														
45	29.7	28.1	26.9	25.9																	
50	30.8	29.2	27.9	26.9																	
55	31.8	30.1																			
60	32.8	31.1																			

YIELD TABLE
(Before thinning statistics upto Col. 7)

Age (yrs)	Dominant		Mean diameter by basal area method (cm)	Number of trees/ha	Basal area/ha (m^2)	Total Volume/ha (m^3)	Volume Thinned (m^3)	M.A.I. (m^3)
	Height (m)	Dia. (cm)						
Good sites								
10	13.5	23.0	17.1	557	12.78	9.65	0.31	0.965
15	16.3	25.3	19.2	499	14.43	20.89	0.62	1.413
20	18.3	27.0	21.0	440	15.22	31.31	1.18	1.612
25	19.9	28.5	22.6	390	15.66	40.09	1.60	1.688
30	21.1	29.7	24.1	349	15.94	47.53	1.93	1.708
35	22.1	30.8	25.5	315	16.13	53.85	2.12	1.700
40	23.0	31.8	26.9	287	16.26	59.38	2.35	1.679
45	23.8	32.6	28.2	262	16.36	64.01	2.25	1.647
50	24.5	33.4	29.4	242	16.44	68.48	2.38	1.617
55	25.1	34.0	30.6	224	16.50	72.40	2.44	1.584
60	25.6	34.6	31.8	208	16.55	75.93	-	1.552
Moderate Sites								
10	10.6	21.1	15.8	557	10.94	3.23	0.01	0.323
15	13.3	23.5	17.9	504	12.64	9.96	0.14	0.665
20	15.3	25.4	19.6	460	13.92	18.00	0.39	0.907
25	16.8	26.9	21.2	416	14.67	26.00	0.72	1.061
30	18.1	28.3	22.6	376	15.15	33.34	1.07	1.153
35	19.2	29.4	24.0	341	15.49	39.64	1.27	1.199
40	20.1	30.5	25.3	312	15.72	45.47	1.54	1.227
45	20.9	31.4	26.6	286	15.90	50.52	1.65	1.237
50	21.6	32.2	27.8	264	16.04	55.12	1.82	2.238
55	22.3	32.9	29.0	244	16.15	59.15	1.84	1.232
60	22.8	33.5	30.1	227	16.24	62.97	-	1.224
Poor Sites								
10	8.0	18.8	14.6	557	9.33	0.57	0.14	0.057
15	10.4	21.5	16.5	504	10.78	3.57	0.28	0.247
20	12.3	23.5	18.2	460	11.93	8.22	0.11	0.432
25	13.8	25.1	19.7	429	13.04	13.94	0.21	0.579
30	15.1	26.5	21.1	396	13.83	19.89	0.39	0.688
35	16.2	27.7	22.4	365	14.38	25.76	0.64	0.768
40	17.1	28.8	23.6	336	14.79	31.30	0.79	0.827
45	17.9	29.8	24.8	311	15.10	36.34	0.99	0.864
50	18.7	30.7	26.0	288	15.34	40.96	1.11	0.890
55	19.3	31.5	27.1	268	15.53	45.29	1.25	0.908
60	19.9	32.2	28.2	250	15.69	49.25	-	0.919

CONCLUSION

It has been generally observed that the stands are either understocked or overstocked.There are very few cases where the stands are fully stocked. Thus the normal yield tables based on the assumptions that the stand is fully stocked does not indicate a correct assessment of the growing stock. To obviate this difficulty, basal area has been taken as basis to express relative stocking. It is easily and quickly determined and closely related to the volume. This approach has the advantage of not requiring samples to be fully stocked. Samples of any density can be used since the diameter is measured as a variable for the solution.

For the present study only 10 sample plots could be located which are distributed in Haldwani, Tarai & Bhabhar, Siwalik, Ramnagar, Lansdowne divisions and Silviculture nursery at Clutterbuckganj (Bareilly).

The Yield Tables for Good Sites, Moderate Sites and Poor Sites have been calculated with the help of regressions. Two constraints were imposed in generating tables. These are that number of trees in lower quality cannot be less than the number for the same age in superior quality and secondly, that the preceding age class cannot have less trees than the succeeding one.

The study reals that for maximum heartwood production there should be 557 trees at 10 years of age. The period of harvest should be kept 30, 50 and 60 years for good, moderate and poor sites respectively.

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6

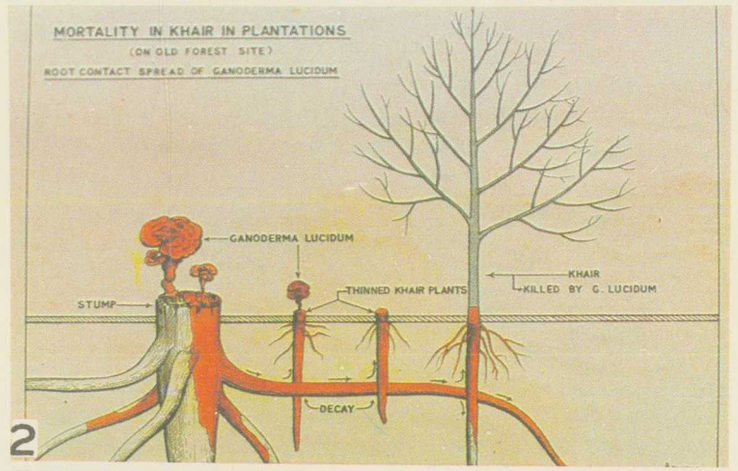
DISEASES

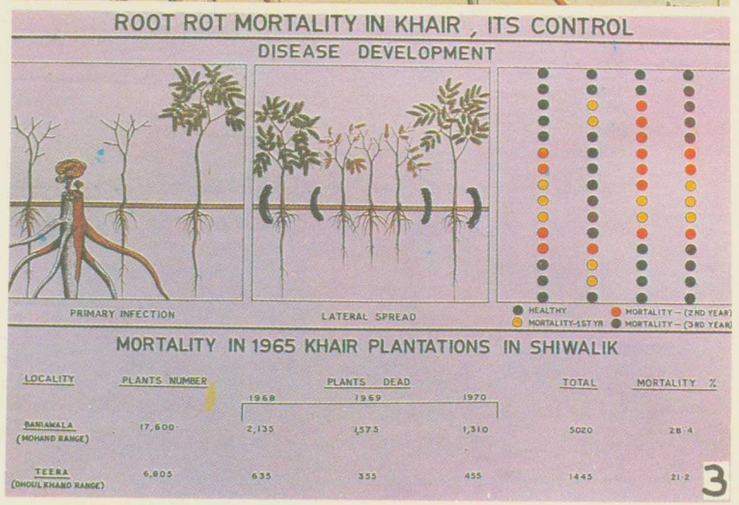
Acacia catechu like several tree species of economic importance in India does not suffer from any serious disease in natural stands where it grows mixed with other tree species. However, serious disease problems may crop up in plantations when it is raised as a pure crop or subjected to abuse like lopping of branches or injuries caused by animals. A review of literature shows that a few diseases have been recorded on this tree species and only two of them namely *Ganoderma* root rot and *Phellinus badius* heart rot have the potentiality to cause great economic losses. An account of the diseases and their management is given here.

ROOT DISEASES

Ganoderma root rot

The disease is endemic in natural forests because of the variability of forest composition. In natural stands the resistant and less susceptible hosts serve as checks and buffers and do not allow the disease to assume a serious proportion. However, it may cause serious root rot mortality in reforested stands uncleared of residual roots and stumps of the previous forest cover. The disease is caused by *Ganoderma lucidum* which is known to possess a wide host range among broad-leaved species which go into the composition of natural forests. The common genera that are attacked by the pathogen are *Acacia, Albizia, Areca, Cassia, Casuarina, Cocos, Dalbergia, Delonix, Eucalyptus, Hevea, Lannea, Leucaena, Morus, Pongamia, Pterocarpus, Sterculia and Terminalia* among others. *Ailanthus excelsa, Holoptelea integrifolia* are, however, resistant and *Bombax ceiba* is attacked only when vigour is poor.





Pl.6.1, 1-3 Acacia catechu 1.Diseased tree with sporophores of Ganoderma lucidum 2-3 Charts showing mode of transmission and management of Ganoderma root-rot

Affected plants exhibit pale foliage which ultimately dries up. Young plants are killed soon after infection whereas mature trees are killed after a protracted period when all the roots become infected and water economy of the plant is greatly impaired. The infected roots show characteristic white fibrous rot where the fungus produces thin white mycelial mat between the bark and the wood. The fungus, a root inhabitant, does not have free access in the soil. However, it possesses ectotrophic growth in the form of small, thin mycelial aggregates on the bark of roots and also on solid objects like stones and soil lumps which are in direct contact of the root. Lateral spread of the disease in the plantation, where it is raised in lines, is through root contact or grafting. Mortality starts from the third year and increases with age of the plantation. When the forest is clear felled, the host resistance is lost and *Ganoderma* quickly spreads on residual roots and stumps of infected trees and builds up a high inoculum potential. If such a site is not cleared of, infected stumps and roots, the susceptible species like khair subsequently planted as a reforested crop becomes infected. The characteristic sporophores of the fungus are developed on affected plants usually at the base or apparently on the ground but in the latter case the sporophores are invariably attached to the underlying decayed roots. Sporophores are usually stalked, sessile, corky and later becoming woody (Pl. 6.1, Fig. 1). The upper surface of the sporophore is shiny laccate and lightly zoned whereas the lower or hymenial surface is white when fresh turning light brown on drying with innumerable pores. Seedlings of khair develop deep tap roots which may come in contact with old roots infected by *G. lucidum* lying deeply buried in the lines and contract the disease. The lateral roots are poorly developed initially but become long spreading when seedlings are 3-4 years old. Such lateral roots may come in contact with the old roots and stumps in between the lines and contract the disease. Both types of infections are responsible for initiating new infection centres in the lines.

The development of new infection centres in lines declines with increase in plantation age because the infected roots of the previous stand disintegrate in course of time. On the other hand, the lateral spread of the disease which is nearly absent in early age increases with plantation age. An assessment of loss of trees in a planted stand has revealed mortality as high as 40 per cent at 7 years' age of the plantation (Bakshi et al., 1976). In a recent survey conducted by Mehrotra and Pandey (1994a) in a 20-yr. old pure khair plantation spread over ten hactares in Haryana, the incidence of the disease was 15 per cent including infected standing trees and those removed earlier as evident from gaps in lines and sporophore formation on cut stumps.

Management of the disease

Since the disease appears when maximum damage to the root system is already done by the pathogen, chemical control which is cost prohibitive and also environmentally hazardous is not feasible. Hence emphasis has been laid on sound silvicultural and management practices aimed at creating conditions favourable for the growth of plants and at the same time unfavourable for the growth and spread of the pathogen. Integrated management of the disease includes measures such as (1) mechanised plantations in the plains to remove stumps and roots of the previous crop, (2) mechanical extraction of stumps roots in slopy areas where tractor ploughing not possible, (3) digging of isolation trenches of the size 0.3 m wide 0.7 m deep and 5 m

across the lines to contain the disease within the trenched area. It is preferable to dig an additional trench on either side of the diseased trees including one apparently healthy tree presuming to harbour the infection in its initial stages, (4) planting resistant species like *Ailanthus* having a rotation age of 10 years and semul about 40 years in the first rotation and by that time the infected stumps and roots are likely to be wiped out due to biodegradation by soil microorganisms, and (5) raising khair in intimate mixture with resistant species in order to break the continuity of pure lines of khair and thereby prevent lateral spread of the disease (Pl. 6.1, Figs. 2&3).

Polyporus root rot

The disease is caused by *Phellinus gilvus (Polyporus gilvus)* which is a wound parasite and attacks roots and tree bases. The fungus attacks the sapwood and causes white spongy rot with characteristic zone lines. It is a weak parasite and does not cause any serious damage to forests (Bakshi, 1976).

Fusarium root rot

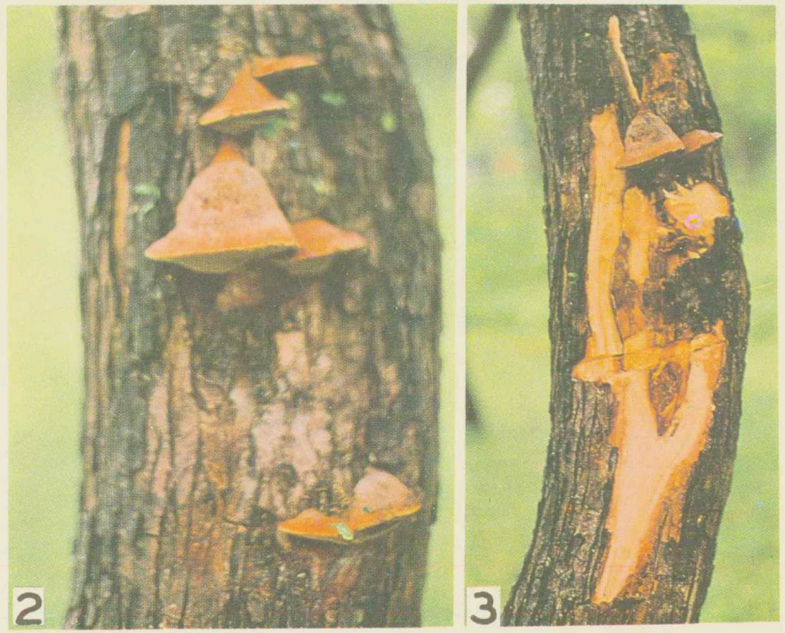
Root rot caused by *Fusarium* sp. takes a heavy toll of seedlings and at times mortality to the extent of 50 per cent has been recorded in forest nurseries. Infected seedlings show the typical wilt symptoms. The foliage becomes flaccid, droops and ultimately dries up. The pathogen being a soil inhabitant becomes active under high soil moisture conditions and high organic content in beds. The disease can be managed by avoiding high dose of FYM and drenching the soil with 0.2 per cent Bavistin before regular monsoon rains set in.

STEM DISEASES

Heart rots

Heart rot caused by *Phellinus badius (Fomes badius)* commonly occurs in natural as well as planted stands throughout its range of distribution. Injuries inflicted to trees due to lopping or damage caused by porcuppines increase the incidence of heart rot. Shukla (1992) reported heart rot incidence to the extent of 23-40 per cent in Pathri Range and Mohand Range respectively. In a recent disease survey conducted in a planted stand raised close to human habitation by village panchayat at Kishanpura, Kaleswar Range, Haryana state, it was found that heart rot incidence was 15 per cent in one plot containing 500 trees whereas in an adjoining plot which was close to the human dwelling the heart rot incidence was 40 per cent and majority of trees showed multiple infection as was evident from the characteristic fruit bodies of the fungus at different heights on the stem (Mehrotra and Pandey, 1994b).

Phellinus badius is a wound parasite which infects trees through injuries due to mechanical causes and damage caused by animals. The fungus attacks heartwood and decays it whereas sapwood remains healthy. Infected trees continue to grow without any outward appearance of being unhealthy. The heartwood is decayed progressively with age and becomes useless for cutch and katha, the two important constituents for which khair is planted as a cash crop. Infected trees commonly show multiple infection and can be marked out from development of fruit bodies of the fungus on the stem at different heights. In initial stages, the colour of the heartwood changes to a deeper



Pl.6.2 .1-3 Acacia catechu 1.Tree showing Witches' Broom 2. Trunk with sporophores of Phellinus badius 3. Trunk showing sporophores and exposed decayed heartwood

shade. In advanced decay the hard, durable and heavy heartwood becomes yellow, spongy and light and presents a mottled appearance due to formation of long, black, indistinct streaks and zone lines.

Sporophores are perennial, sessile, hard, woody and easily detachable from the host (Pl. 6.2, Fig. 2&3). The upper surface is brown or black, cracking with age and the lower or hymenial surface is dull brown with minute pores. The spores are yellow-brown, round to oval and thick-walled (Bakshi, 1971).

Management of heart rot includes measures to avoid injuries to trees and systematical removal of sporophores of the fungus being easily detachable and their disposal by burning. In khair, trees above 20 cm d.b.h. are marked for felling green but disease trees below this exploitable diameter class are normally not removed. During cultural and particularly felling operations, decayed trees bearing sporophores should be removed irrespective of diameter class and timber salvaged.

Phellinus senex (*Fomes senex*) commonly occurs in plants as wound parasite on a variety of hardwood species including *A. catechu* and causes white stringy rot in heartwood. Sporophores on stem are resupinate effuso-reflexed or sessile, attached by a broad base usually imbricate, corky, becoming woody later. The upper surface is greyish brown, rough and zoned whereas the hymenial surface, is reddish brown and smooth with round pores. The spores are hyaline and thin-walled.

Phellinus fastuosus (*Fomes fastuosus*) is a butt rot fungus which causes white pocket rot. In the initial stages the wood develops dark brown stain and later pockets are developed which are filled with decayed fibres. In later stages the pockets appear empty and brown on disintegration of the fibres. Sporophores are woody with dull brown to almost black, slightly cracking upper surface and dark brown hymenial surface with pores. The spore mass is yellow (Bakshi, 1976).

Ganoderma applanatum is associated with heart rot in khair. The fungus is a wound parasite and known to enter through roots or lower portion of the trunk and causes white rot. Sporophores are perennial, sessile or rarely substipitate, applanate, reflexed, single or imbricate, corky soon becoming hard and woody. The upper surface is dull brown to blackish, zoned, uneven and crusty whereas the hymenial surface is white when fresh but turning light yellow or light brown on drying and has round pores. The spores are brown, broad ellipsoid, truncate and thick-walled (Bakshi, 1971).

FOLIAGE DISEASES

Powdery mildew

Two fungi causing mildews are known to attack foliage of khair. *Phyllactinia acaciae* is recorded from Sagar, Madhya Pradesh (Tandon and Chandra, 1964) and *Erysiphe acaciae* from Poona, Maharashtra (Browne, 1968).

Leaf rust

Ravenelia tandonii, the leaf rust commonly occurs on *A. catechu* in North India. Minute uredinia and telia develop below the cuticle on the upper surface of pinnules

with chestnut brown spore heads. The infected pinnules are shed prematurely (Bakshi and Sujan Singh, 1967).

Leaf spot

The disease is caused by *Microstroma acaciae* and it has been recorded from Majhgawan, Uttar Pradesh by Sydow et al. (1937). The fungus produces snowy white tufts on lower leaf surface.

SEED AND POD MYCOFLORA

A phomopsis sp. has been recorded on seeds of *A. catechu* from Dehra Dun. The fungus attacks the seeds while they are inside the pods on trees. Seeds are deformed due to fungal attack and majority of them fail to germinate. About 10-15 per cent loss of seeds has been reported (Mehrotra and Sharma, 1992). Out of several fungi recorded on seeds *Alternaria, Aspergillus* and *Curcularia* have been found to cause 30-60 per cent rotting of seeds and seedlings (Paul and Bhardwaj, 1987). Mehrotra et al. (1994) recorded severe attack on pods by *Erysiphe* sp. during winter months from Dehra Dun. The fungus sporulates abundantly almost plastering either side of the pod with powdery masses of conidia and develops spherical cleistothecia (Pl. 6.3, Figs. 1 to 3).

PHYTONEMATODE

The root knot nematode, *Meloidogyne javanica* has been recorded on khair from Dehra Dun. The nematode parasitises the roots and form galls which are quite variable in number. The nematode is polyphagous and is reported to infect a number of other tree species (Sharma and Mehrotra, 1992).

WITCHES' BROOM

Witches' broom commonly occurs in *A. catechu* plantation in Uttar Pradesh. The incidence of the disease is moderate to heavy. Trees of all ages are attacked. Infected trees show repeated branching of twigs as a result of which the clusters of branches formed appear in the form of broom hence the name witches' broom. The cause of malformation is not known (Pl. 6.2, Fig. 1).

PHENEROGAMIC PARASITE

Macrosolen cochinchinensis is the only mistletoe known to parasitise khair (Browne, 1968).

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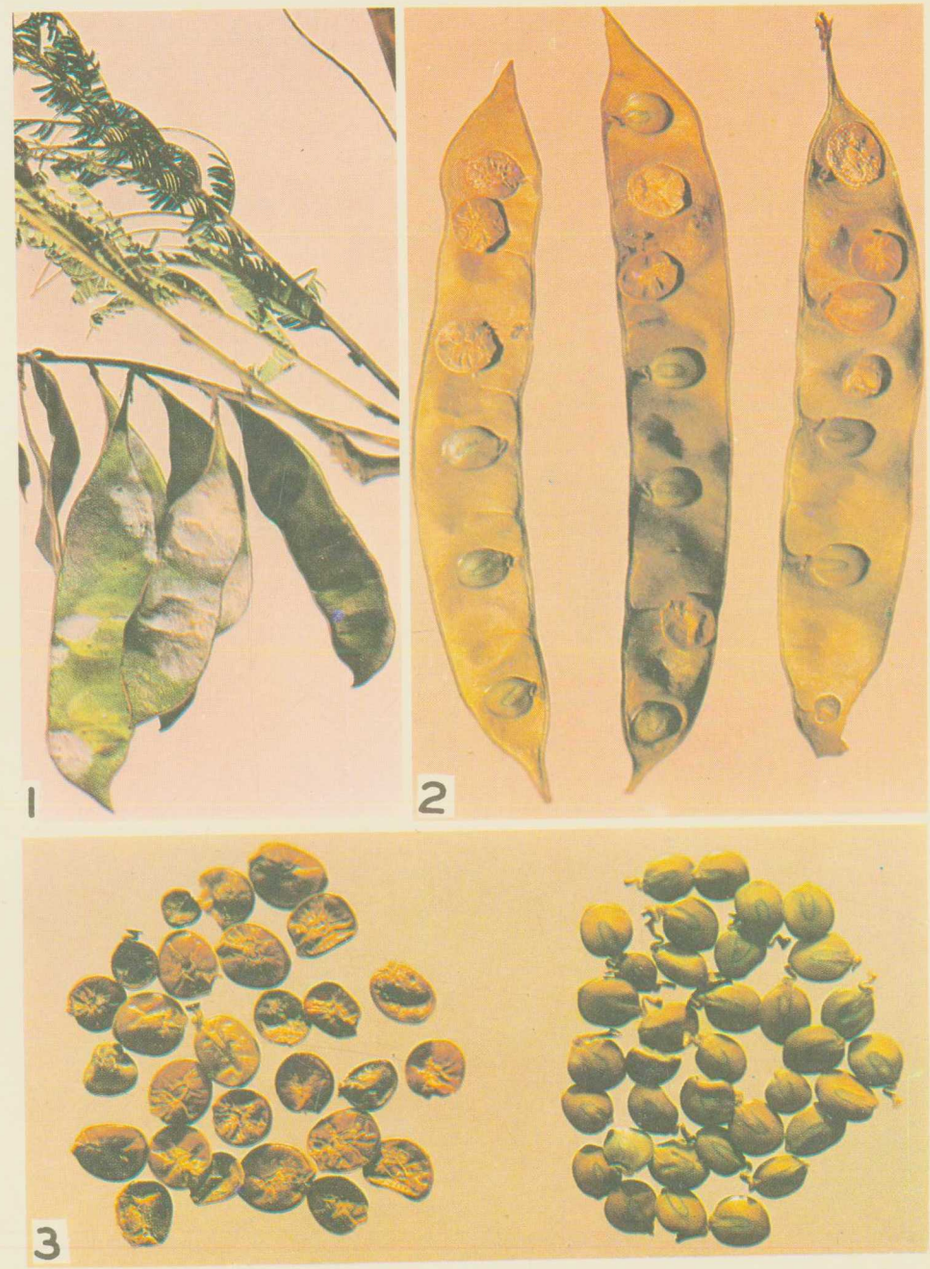

Pl.6.3 .1-3 Acacia catechu 1. Pods infected with Erysiphe sp. 2.Pods with deformed seeds infected by Phomopsis sp. 3.Deformed and healthy seeds

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7

INSECTS AND PESTS

Acacia catechu Wild, popularly known as khair, while growing under healthy environment is by and large, resistant to drought, frost, fungi and insects, though seedlings and young plants are apt to suffer sometimes seriously, in growth and development, during the first few years. Of the 58 and odd insect species recorded by Bhasin and Roonwal (1954) on *Acacia catechu*, the most dominant group belongs to the order Coleoptera with 25 genera and 33 species under 8 famlies, followed by Lepidoptera, (13 families, 20 genera and 22 species) and Homoptera with 3 genera and 3 species under 2 families. Among these, while *Celosterna scabrator* Fab. (Coleoptera : Cerambycidae) and *Cryptothelia crameri* Westwood (Lepidoptera : Psychidae) are serious pests of living khair trees, there are several (approx. 23 species) other pests on felled wood both in the field and under storage conditions. The remaining insect fauna associated with this species is of sporadic nature and are simply casual feeders (minor pests). A check list of insect pests of *Acacia catechu* is given as Appendix I.

A. DEFOLIATORS AND LEAF ROLLERS

(a) Coleopterous defoliators

Of the 33 species of beetles, which have been recorded from *Acacia catechu* Wild, about 8 species viz. Buprestidae (2- species), Chrysomelidae (2-species), Curculionidae (3-species) and Scarabaeidae (1-species) are associated with the defoliation of foliage of this tree species. Most of the species are polyphagous, which apart from *Acacia catechu*, have also been recorded defoliating many other plant species within the range of their distribution. The food and the environment of the adult beetles are invariably different from those of its larva. While the beetles live freely in the open, the larvae live in concealed environment/shelter in different media (Beeson, 1941). The two chrysomelid species, *Diapromorpha turcica* Fabr. and *Mimastra cyanura* Hope are widely distributed leaf beetles in the Indian region. The adults feed on foliage of several dicotylendonous tree species and shrubs. The larvae live in the soil. The beetles of the later species, *M. cyanura* Hope emit an acrid yellow fluid from the head. None of the species have occurred as major pest, though occasionally they have been reported as minor pests. The family curculionidae (Snouted Weavils) is represented by three species on *Acacia catechu*. While the beetles have been reported to feed on the leaves of the host plants, the larvae are soil dwellers, feeding on the roots of several plants species but have not been reported to be injurious in forestry crops. (Beeson, 1941; Browne, 1968 and Bhasin and Roonwal, 1954).

(b) Lepidopterous defoliators

This is by far the largest group of defoliators (nearly 17 species) and constitute the single most important component of insect fauna, found responsible for most of the damage in khair nurseries and plantations, particularly the young plantations. Of the 17 species, the family Geometridae is represented by six species, Noctuidae (3-species), Cosmopterygidae, Gelechiidae (2- species each).

Family Cosmopterygidae

Two species of this microlepidopterous family, *viz. Ascalenia antidesma* Meyrick and *A. gastrocosma* Meyrick are common in India and Pakistan. The larvae of both these species are minor defoliating pests of *Acacia catechu*. They bind or fold together the leaflets of the host plants and feed on them. The fully mature larvae drop to the ground by a silky thread and pupate in a cocoon among the leaves or in the soil. While in *A. antidesma* the pupation occurs in July, with pupal period of six days, in the second species, *A. gestrocosma*, it occurs in May-June with pupal period of 5 days. The species occurs only as minor pest.

***Eucosma stercoma* Meyrick**
(Lepidoptera : Tortricidae)

Occurs widely in India. A small moth. The larvae are greyish yellow or yellowish brown. They are leaf rollers of leguminous plants and have been recorded feeding in the rolled up terminal leaves of *Acacia catechu* and *Pithecellobium dulce* (Beeson, 1941). Pupation occurs in a white elongate oval cocoon concealed among the leaflets of the host (Fletecher, 1933). The species occurs only as a minor pest.

***Hyposidra talaca* Walker**
(Lepidoptera : Geometridae).

The larvae of this species feed on several tree species, including *Acacia catechu* and shrubs in India and adjoining countries within the oriental region. In India it frequently occurs on *Tectona grandis* in association with the closely related *Hyposidra successaria* (Beeson, 1941). The female lays several hundred eggs in a batch on the foliage of the host plants. The brown looper larva with white spots feeds openly on the leaves and inflorescence. The leaves may be eaten away gradually from the edges. The

feeding may also occur at large isolated holes on the inner surface of the leaves. Pupation occurs without a cocoon in the top soil. In India the life cycle lasts for about five weeks in monsoon (July-September) (Beeson, 1941), however, according to Kalshoven (1950-1) length of the life cycle varies from about 2.5 to 3.5 month at an altitude of 1700 m in Java. Although common in many parts of its range, the species does not occur as a major forest pest.

***Semiothsia* spp.**
(Lepidoptera : Geometridae)

Two species of the genus *Semiothesia, viz. S. fidoniata* Guenee and *S. pluviata* Fab. occur widely in India and Pakistan. The looper larvae of both these species have been reported injurious to foliage of various leguminous plants within the range of their distribution, specially recorded on *Acacia catechu* and *Albizzia procera*. While, *S. fidionita* is reported as a pest sometimes in epidemic forms on *Acacia catechu* growing in lac plantations at the end of monsoon, larvae of the second species, *S. pluviata*, have been reported to defoliate young plants of both *Acacia catechu* and *Albizzia* spp. The female lays right green eggs singly or in clusters on the buds and young leaves of host. The fully grown larvae are about 25 mm long and are variably grey or greenish with yellow lateral strips. They feed openly on the leaves. The larval period lasts from 3 to 4 weeks. Pupation occurs in the soil, with pupal period of 2 to 3 weeks. The life cycle is of about 6-7 weeks. The species has not been reported as an important pest.

***Beralade similis* (Walker)**
(Lepidoptera : Lasiocampidae)

The larvae of the eggar moth, *Chilena similis* are regular defoliator of of *Acacia catechu* and *A. nilotica*. in India and Pakistan. The feeding occurs during early monsoon months. The species undergoes pupation in August and the adults emerge in September or October. The larvae offspring of this generation enter a prolonged pupal stage in brownish white cocoon in November and do not become adult till June in the following year. There are 2 generations during a year. (Beeson, 1941).

***Pericyma umbrina* (Guenee)**
(Lepidoptera : Noctuidae)

A common species in India and Myanmar and probebly also present in Pakistan. The larvae of this noctuid moth feed on the leaves of *Acacia* spp. and have been recorded as defoliators of *Acacia catechu, A. modesta* and *A. suma* (Beeson, 1941; Bhasin & Roonwal, 1954). Colouration of the larvae vary from black to almost entirely green. The fully grown larva is of about 35 mm long. During the south-west monsoon, the pupal period varies from 10 to 14 days (Beeson, 1941). The species is not reported as a major pest.

***Stauropus alternus* Walker**
(Lepidoptera : Notodontidae)

Generally known as Lobstor caterpillar, this moth is widely distributed in the oriental region. A large but inconspicuous, greyish moth, suffused with darker shades and a marginal row of reddish brown and pale spots on wings with wing span of about 4

to 6 cm. The larvae are polyphagous on the foliage of dicotyledonous plants. The female lays eggs on leaves of the host. Pupation occurs between leaves, spun together with silk or on twigs. The life cycle varies from 6 to 8 weeks in southern India and Srilanka, with egg, larval and pupal period of about 1,4 to 5 and 3 weeks respectively. Outbreaks have been reported from Srilanka, (Hutson, 1932). It is known as an occasional pest of tea in India, Java and Srilanka. Other recorded hosts include *Acacia catechu, A. dealbata, A. mearnsii, Albizzia chinensis, Cassia fistula, C. javanica, Grevillea robusta, Mangifera indica, Ougeinia dalbergioides, Palaquium gutta, Syzygum cummsn, Tamarindus indica, Trenvia nudiflora* and *Xylia xylocarpa* (Beeson 1941, Mathur and Singh 1954-61).

***Macrobathra notomitra* Meyrick**
(Lepidoptera : Occopheridae)

A common species in India and Pakistan. The species is a minor pest on the foliage of *Acacia catechu*. The young larvae borers in very young and tendu leaf stalks, latter binds together the leaflets with silk to form a shelter and feed on the leaf tissues. The pupa is formed in a flimsy cocoon within the larval shelter and overwinters in pupal stage (Beeson, 1941).

B. STEM AND ROOT BORER

***Sinoxylon atratum* Lesne**
(Coleoptera : Bostrychidae)

Sinoxylon atratum Lesne is one of very few bostrychid beetles, the larva of which have been recording boring into living saplings or advanced seedlings boring into living saplings or advanced seedlings of *Santalum album* in Salem (Tamilnadu), making an axial tunnel and leading to one back in the upper parts of the plant. It has been reported as one of the borers of dying saplings of *Artocarpus hirsuta* in south Mangalore (Karnataka).

***Celosterna scabrator* Fabr.**
(Coleoptera : Cercembycidae)

Celosterna scabrator Fabr. (Coleoptera : Lamiidae) popularly known as "babul stem and root borer", is principally a borer of *Acacia* sp. and *Casuarina equisetifolia* in plantations, but is also a pest of other host plants such as *Prosopis* spp., *Shorea robusta, Tectona grandis* and *Zizyphus jujuba*. Of late, it has developed fancy for *Eucalyptus* and has adopted it as a new host. (Chatterjee & Singh, 1967; Thakur, 1988). Roots and stems of young (1-3 years) *Eucalyptus* plants in plantations are reported to have been damaged in some parts of Andhra Pradesh, Madhya Pradesh, Maharashtra and Uttar Pradesh, particularly in areas which were earlier occupied by its principal host (Chatterjee, Sen-Sarma, 1968; Sen-Sarma & Thapa, 1981; Sen-Sarma, 1986; Thakur, 1988).

The adult attacks tender shoots of the plant, scraping and feeding in the bark up to sapwood. Only one egg is laid per plant. Larva, on emergence, bores in stem and root which is hollowed out. Dust is thrown out through ejection hole. The infested plant

shows signs of wilting, yellowing and ultimately the death of the plant. The pest has the potential of becoming a major pest of *Eucalyptus*.

Xystrocera globosa **Olivier**
(Coloptera : Cerambycidae)

Very widely distributed in the Madagaskar and Asian regions, with further extension eastwards to Hawaii and Puerto Rico. A reddish brown longhorn beetle, ornamented with metallic blue or green lines. The beetle which breeds in various dicotyledonous trees, notably *Albizias*, for which it exhibist some preference (Browne, 1968). The larva tunnels mainly in the inner bark of the host, making groves in the sapwood superficially. It pupates in a cell thinly lined with calcium carbonate. In trees with thick bark, a heavy infestation reduces more than half the thickness of the bark to dust so that the bark readily separates from the wood. The pupal period lasts about three weeks. The developmental period in India is very variable, from less than one year to about 2 years. Emergence occurs almost every month, but mainly in May, June and September. (Beeson, 1941). The species is principally a pest of ornamental and shade trees.

The species is notable in India and Srilanka as pest of avenue roadside trees and of shade trees in tea plantations particularly of *Albizias*, attacking those that are injured or sickly and hastening their death. The less resistant trees may be killed in one season by a heavy infestation; more resistant trees may produce callus that restricts attacked patches of bark. *X. globosa* is also a pest in Malaya, and in Egypt was responsible for the disappearance of *Albizzia lebbek* in several cities.

Its recorded hosts include *Acacia catechu, Acrocarpus fraxinifolius, Albizia chinensis, A. falcata, A. lebbeck, A. odoratissima, A. procera, Bombax malabaricum* and *Xylia xylocarpa.*

Bucolarcha glodes Meyrick (Fam. Gelechiidae) attacks seed pods of *Acacia catechu*. The larvae bore in the pod and feed on it.

C. SAP SUCKERS

Three Homopterous species belonging to two families, Coccidae, (2-species) and Cicadellidae (1-species), are important sap suckers, which are involved in the damage to *Acacia catechu*. All these species are polyphagous with a wide spectrum of host plants of forestry species. They feed on the sap of leaves, branches and young shoots. (Beeson, 1941; Browne, 1968).

Lecanium hesperidium Linn.
(Homoptera : Coccidae)

Commonly known as "Soft Scale" is very widely distributed species in tropics and sub-tropics and milder parts of the temperate zones and in more severe climates, sometimes occuring as a green house pest.

In most localities, this soft bodied, elongate, brownish or pale yellow scale insect overwinters as a half grown nymph and reproduction occurs in the early summer.

Both the adults and nymphs feed on the sap of the host and excrete honey dew, for the sake of which they are tended by ants in the oriental region. It is not considered as a serious pest in Forest plantations.

The species has a wide range of host plants, belonging both to conifers and dicotyledons including *Acacia catechu* in India.

Oxyrachis tarandus Fabr.
(Homoptera : Cicadellidae)

This species is widely distributed in Africa and southern Asia, including India and Pakistan. Nymphs and adults of this tree hopper feed gregariously on the sap of shoots of dicotyledonous trees, including forestry species. The eggs are laid in the bark of the shoots in characteristic V shaped slit cutout by the ovipositor. This injury often results in the stunting or death of the infected shoots. The nymphs, like adult, feed on the same shoot. They are attended by species of ants, (*Camponotus* and *Crematogastor*) which feed on honeydew. There are 5-6 generations in a year in northern India. (Chatterjee, 1941).

This tree hopper is polyphagous and is recorded as a pest of *Acacia catechu, A. nilotica indica, Albizia chinensis, A. lebbeck, Cassia fistula, Dalbergia latifolia, Prosopis juliflora, P. spicigera, Santalum album* and *Tamarindus indica* (Beeson 1941; Chatterjee, 1941; Mathur and Singh 1954-61).

D. HARVESTED WOOD

After the foliage feeding insects, harvested timber pests are the second largest group of insects, which have been found associated with damage to felled and converted wood of *Acacia catechu* . There are nearly twenty four species of Coleopterous beetles, *viz.* Bostrychidae (9), Buprestidae (4), Cerambycidae (8), Curculionidae (1), Platypodidae and Scolytidae (1 each) and termites (Isoptera) (2). Of these, species of genera *Sinoxylon* (Bostrychidae), *Stromatium barbatum* (Cerambycidae), *Platypus solidus* Walker (Platypodidae), *Xyleborus* sp. (Scolytidae) and termites (Termitidae) are by far the most important wood borers of the harvested wood of *Dalbergia latifolia*.

Family : Bostrychidae

Heterobostrychus hamatipennis **Lesne**

Of the nine species of Bostrychidae, the species of *Heterobostrychus hamatipennis* Lesne, and six species of *Sinoxylon* are the important powder post beetles recorded on *Acacia catechu*. Beetle and larvae bore in sapwood of dead wood. The species occurs throught the oriental region. It is a black cylindrical beetle with a rough hooded prothorax and usually curved hooks or profections at the hind ends of elytra. The female beetle usually lays eggs on the rough surfacs of logs from which the bark has been removed or penetrate inside natural crevices and holes and may even bore a short tunnel into the wood for the purpose of feeding and oviposition. Eggs are deposied singly and the larva bores longitudinotes a gradually widening tunnel which may reach a length of 37 cm and a diameter of quarter of an inch. In a crowded infestation a

tunnel is usually much convoluted, changing direction and intersecting the tunnel of other larvae. It is tightly packed with moderately fine wood dust much of which must have passed through the alimentary canae of the larva. Traces of starch may be present but most of it is digested. The larva is 17 mm and is described by Gardner (1933). The life cycle is annual with emergence in June-July (about 70% in June).

Its recorded hosts include *Acacia, Anogeissus latifolia, Bamboos, Bomax malabaricum, Boswellia serrata, Canarium strictum, Dalbergia sissoo, Dendrocalamus strictus, Syzyzium cumini, Garuga pinnata, Machilus* sp., *Mallotus phillipinensis, Mangifera indica, Quercus* sp., *Shorea robusta, Terminalia belerica, Vatica lanceaefolia.*

***Sinoxylon* spp. Lesne**
(Coleoptera : Bostrychidae).

All the six species of *Sinoxylon* reported from *Acacia catechu* constitute an important group of wood borers. They are polyphagous with a very wide spectrum of host plants within the oriental region. They bread in small branches, twigs or logs of the hosts. The larvae bore in the sapwood with extensive gallery system and which are packed with fine powder. The life cycle is variable. Whereas there may be four life cycles in one year in the warmenst parts, where no true winter season intervenes. But normally the quickest rate of development is attained by only a small proportion of the population arising from each broad of eggs, the majority developing more slowly and taking periods equivalent to two and three or more short life cycles. This slowing down of the rate of growth is apparently due to differential nutrition in the larval and immature beetles stages as well as to delay impairing and ovipositing in the free adult stage. (e.g. *S. crassum*) to as long as one year (*S. atratum*).

Logs of all sizes are attacked shortly after they are felled and are inhabited as long as the wood remains moist and sappy. Seasoned or dry timbers are not attacked. Beetles are abundant during September-November and March-April, less so during the colder months and are very scarce in the hot dry weather. The life cycle is of 2 or 3 months duration. The emergence period of each gneration usually lasts for 3 months but this may be extended to 5 months in north India. (Beeson, 1941; Browne, 1935).

A wide spread and common species, very variable in size and markings. It has been recorded from a large number of host plants. It frequently bores into the wood of standing, dying or recently dead trees but does not always establish egg tunnels. The beetle is active in full sunshine and at very high temperatures. Emergence of adult beetles is maximum in the last third of April. It is possible for three life cycles to be completed in a year as the emergence records of seperate infestations show a secondary monsoon swarming at the end of June and begining of July and a third period of increased emergence at the begining of October. Beetles emerge in all intermediate months except January-March but a large proportion of each broad is composed of individual of delayed development, may of which must remain in the wood for a year. The longest period of infestation observed is three years.

***Stromatium barbatum* Fabr.**
(Coleoptera : Cerambycidae)

This species is an important pest of packing cases and woodworks in houses, rafters, panels, plywood and military stores. Furniture and other woodwork in buildings do not show any evidence of its presence for several years, before it is detected in the form of ejected dusts, noise of larval activity, exit holes, breakage, etc. In the majority of cases, the delayed appearance of damage is due to the long larval life. New attack on seasoned timber in buildings is usually an indication of neglect of a previous infestations.

About 350 different kinds of logged wood are attacked by this species. It is found throughout India, Mynamar and Srilanka and also in Mauritius and Madagascar. It is supposed to have been introduced into England in tea-chests from India. (Beeson, 1941, Browne, 1968).

Beetle reddish brown to almost black, covered with a tawny pubescence. Beetles are nocturnal in habit, hiding in dark shelters during day time. Female beetles lay eggs in small holes, crevices or fissures in the wood. The larval tunnels are lightly packed with very fine floury dust, much like that of Bostrychidae. The tunnels run irregularly deep into the wood without any external manifestation. In crowded infestations, they criscross and interlace frequently until practically the whole of the interior of the wood, except the very hard zones, is reduced to powder. The outer surface is left nearly intact as paper thin sheets. Dust is not ejected except through holes or cracks accidently formed. *S. barbatum* nests in large logs with the bark on position as well as in thin planks and battens or sheets of plywood. The sound is produced by the scrapping action of the larval mandibles.

Pupation occurs usually in May at various depths in wood. The pupal period lasts for two weaks. The beetle, after exclusion, bores a seperate tunnel to the surface and escapes through an oval or circular exit hole. The life cycle is usually annual, but may prolonged to several years.

The beetles emerge during June and July, rarely also at the end of the May. The initial date and duration of the period of emergence of the beetles in any one year is largely determined by the quantity of the rain at the end of the dry season and beginning of the monsoon and the resulting atmospheric humidity. (Beeson, 1941; Browne, 1968).

***Ceresium leucosticticum* White**
(Coleoptera : Cerambycidae)

This species is common in the Indian subcontinent. Larva bores in sapwood of dead wood of *Acacia catechu, A. pennata, Albizzia lucida, A. odoratissma, Anogeissus latifolia, Careya arborea, Cassia fistula, C. siamea, Castanopsis argyrophylla, Dalbergia fusca, Dolichandrone stipulata, Grewia tiliacfolia, Lagerstromia parviflora, Lannea grandis, Mallotus phillipinensis, Sceutia indica, Tectona grandis* and *Xylia dolabriformis.*

Beetle brownish black, with 9 white spots on elytra, Prothorax, leggs and antennae light brown.

The females lay eggs singly or in groups of two or three on bark of the host. The early larval galleries in some woods for, (e.g. *Grewia tiliaefolia*), are constructed in the bark and bast while in other woods, (e.g. *Anogeissus latifolia*) the galleries descends to the sapwood at once. They are shallow tape like and irregulatly broadened due to repeated working over the same area. Emergence occurs in June to August with 55% in June. Life cycle is annual but emergence may be delayed upto three years in drywood.

***Platypus solidus* Walker**
(Coleoptera : Platypodidae).

Widely distributed in the oriental region and extended to Australia. In India it is common than *Crossotarsus saundersi* and more frequent in the regions with a dry season. Commonly known as shot hole borer, the beetles bore in sapwood of dying trees and newly felled timbers.

Male beetle dark brown, female palar, with the front of the head pilose. Beetles, though usually bore felled or newly dead trees but attack on living (diseased) trees have also been recorded (i.e. Rubber plant). The gallery pattern is of normal type. a horizental or cross sectional plane.

The life cycle varies from 8 and 10 weeks in India. It is probable that immature beetles, which have left the pupal cells, may live in the main tunnels for some time before leaving the wood.

Emergence from an attacked log may occur in most months of the year according to the period and sequence of infestations and may extend even upto about 8 months after the date of felling.

The pin holes of *P. solidus* occur as defects in all timbers that are used for ornamental features. They completely spoil logs intended for peeling for veneers and plywood and for making match splints and match boxes.

***Xyleborus* sp.**
(Coleoptera : Scolytidae)

Beetles bore in sapwood of dying trees and newly felled wood.

The genus *Xyleborus* the largest in the family Scolytidae, a collection of *Ambrosia* beetles inhabiting all parts of the world where trees grow. The size of the beetles range from 1 to 8 mm and the shape from cylindrical to hemispherical or globular and the colour from straw to black.

The females lay eggs in pinhole or shot hole bores in woody tissues or timber. The males do not bore tunnels. In most groups their sole function appears to be mating. The larvae are fusiform with a reduced head and a smooth transverse pronotum (Gardner, 1934).

Many species of *Xyleborus* are polyphagous and breeds in over 100 species of trees.

Life cycle varies from 10 days to a fortnight to the other extreme at which colonies continuously breed for over a year before emerging.

Timber that has been attacked by *Xyleborus* spp. show defects in the form of pinholes or black spots and lines on the sawn surface, which spoil it for ornamental purposes and for special uses as matches, Veneer plywood. Unless heavily attacked, a soft wood is not seriously weakend for structural purposes. They have the best chances of rapidly becoming injurious under favourable conditions.

TERMITES (ISOPTERA)

Apart from several species of coleopterous beetles, two species of subterranean termites, *Microceromes beesoni* Snyder and *M. championi* Snyder, which are reported to cause wide spread damage to stem, stumps and felled wood (logs) of *Acacia catechu*. (Sen-Sarma, *et al.* 1975).

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APPENDIX I

CHECK LIST OF INSECT PESTS OF *ACACIA CATECHU* WILLD.

Order/Family	Name of insect species	Pest Status	Nature of damage (After Beeson, 1941; Mathur & Singh, 1959 and Browne, 1968)
1	2	3	4
A. DEFOLIATORS			
Order : Coleoptera			
Family : Buprestidae	*Sternocera diardi* Gory	Minor	Beetle feed on foliage.
	Sternocera orientalis Herbst.	Minor	Beetle feed on foliage.
Family : Chrysomelidae	*Diapromorpha turcica* Fabricius	Moderate	Beetle defoliates.
	Mimastra cyanura Hope	Moderate	Beetle defoliates.
Family : Curculionidae	*Myllocerus catechu* Marshall	Moderate	Beetle defoliates.
	Myllocerus lefroyi Marshall	Moderate	Beetle defoliates.
	Peltotrachelus juvencus Faust	Moderate	Beetle defoliates.
Family : Platypodidae	*Trigonophorus hookei* White	Minor	Beetle defoliates.
Order : Lepidoptera			
Family : Cosmopterygidae	*Ascalenia antidesma* Meyrick	Moderate	Larva binds together and feeds on them.
	Ascalenia gastrocosma Meyrick	Moderate	Larva binds together or folds leaflets and feeds on them.
Family : Gelechiidae	*Anarsia triglypta* Meyrick	Minor	Larva feeds on leaves.
	Bucolarcha geodes Meyrick	Minor	Larva feeds on pods.
Family : Geometridae	*Buzara suppressaria* (Guenee)	Minor	Larva defoliates.
	Hyposidra talaca Walker.	Minor	Larva defoliates.
	Lomographa subtessellata Walker	Minor	Larva defoliates.
	Semiothisa fidoniata Guenee	Moderate	Larva defoliates. Sometimes in epidemic form.
	Semiothisa pluviata Fabricius	Moderate	Larva defoliates.
	Traminda mundissima Walker	Minor	Larva defoliates.
Family : Lasiocampidae	*Chilena similis* Walker	Minor	Larva defoliates.
Family : Lymantriidae	*Casama vilis* Walker	Minor	Larva defoliates.

(Contd.)

1	2	3	4
Family : Noctuidae	*Erieceia inangulata* Guenee	Minor	Larva defoliates.
	Pandesma quenavadi Guenee	Minor	Larva defoliates.
	Pericyma umbrina Guenee	Minor	Larva defoliates.
Family : Notodontidae	*Stauropus alternus* Walker	Occasional	Larva defoliates.
Family : Nymphalidae	*Eriboea athamas athamas* Drury	Minor	Larva defoliates.
Family : Oecophoridae	*Macrobathra notomitra* Meyrick	Minor	Young larva bores in very tender leaf-stalks; older larva binds together and feeds on leaves.
Family : Psychidae	*Cryptothelia crameri* (Westwood)	Serious	Larva feeds on foliage and prunes leasing shoots, twigs and thorns for forming case.
Family : Tertricidae	*Eucosma stereoma* Meyrick	Moderate	Larva feeds in rolled-up terminal leaves.
Family : Yponomeutidae	*Stasiphron cryptomorpha* Meyrick	Minor	Larva feeds on leaflets.
B. STEM & ROOT BORERS			
Order : Coleoptera			
Family : Bostrychidae	*Sinoxylon atratum* Lenee	Moderate	Beetle and larva bore in sapwood of dead wood.
Family : Cerambycidae	*Celosterna scabrator* Fabr.	Serious	Larva bores in stem and root of young living plant. Beetle feed on bark of young shoots.
Order : Lepidoptera			
Family : Indarbelidae	*Indarbela quadrinotata* Walker	Moderate	Larva bores short tunnel in wood for sheltr during day; feeds at night upon outer surface of bark of green stand-ing tree.
C. SAP SUCKERS			
Order : Homoptera			
Family : Cicadellidae	*Oxyrachis tarandus* Fabr.	Serious	Adults and nymph feed on sap from shoots.
Family : Coccidae	*Kerria hesperidium* Linn.	Serious	Adult and nymph feed on plant sap.
	Lecanium longulum Douglas	Serious	Adult and nymph feed on plant sap.
D. PEST OF TIMBER			
Order : Coleoptera			
Family : Bostrychidae	*Heterobostrychus hamatipennis* Lesne		Moderate Beetle and larva bore in sap-wood.
	Lyctoderma ambiguum Lesne	Moderate	Larva bores in sapwood of dead and dry wood.
	Sinoxylon anale Lesne	Moderate	Beetle and larva bore in sap-wood of dead wood and converted timber.
	Sinoxylon atratum Lesne	Moderate	Beetle and larva bore in sap-wood of dead wood.
	Sinoxylon capillatum Lesne	Moderate	Beetle and larva bore in dead branchwood and dead twigs.

(Contd.)

1	2	3	4
	Sinoxylon crassum crassum Lesne	Moderate	Beetle and larva bore in sap-wood of dead wood.
	Sinoxylon crassum dekkanense Lesne	Moderate	Beetle and larva bore in sap-wood of dead wood.
	Sinoxylon indicum Lesne	Moderte	Beetle and larva bore in sap-wood of dead wood.
	Xylodectes ornatus Lesne	Moderate	Beetle and larva bore in sap-wood of dead wood.
Family Buprestidae	*Aciaeodera aurifera* Cast & Gory	Moderate	Larva bores in small dry branches and roots.
	Aciaeodera stictipennis Cast & Gory	Moderate	Borer in dead wood. Larva bores between bark and sapwood.
	Agrilus villosostriatus Thomson	Moderate	Borer in dead wood. Larva bores between bark and sapwood.
	Anthaxia acaciae Thery	Moderate	Borer in dead wood. Larva bores between bark and sapwood.
Family Cerambycidae	*Celosterna scabrator* Fabricius	Moderate	Larva bores in stem and root of young living plant. Beetle feeds on bark of young shoots.
	Ceresium leucosticticum White	Moderate	Larva bores in sapwood of dead wood.
	Demonax buteae Gardner	Moderate	Larva bore in small dry branches.
	Dere acaciae Gardner	Moderate	Larva bores in dead wood.
	Hypoeschrus indicus Gahan	Moderate	Larva bores in sapwood of dead wood.
	Perissus laetus Lameere	Moderate	Larva bores in sapwood of dead wood.
	Stromatium barbatum Fabricius	Serious	Larva bore in dry wood.
	Xystrocera globosa Olivier	Serious	Larva mainly bores inner bark, but also grooves sapwood superficially. Attacks injured and sickly trees hastening their death.
	Zoodes compressus Fabricius	Moderate	Larva bores in dead wood.
Family Curculionidae	*Mecistocerus fluctiger* Faust	Moderate	Larva bores in sapwood of dead wood.
Family Platypodidae	*Platypus solidus* Walker	Moderate	Shot-hole borer. Beetle bores in sapwood of dying trees and newly felled timber.
Family Scolytidae	*Xyleborus* sp.	Moderate	Shot-hole borer. Beetle bores in sapwood of dying trees and newly felled wood..pa

8

WOOD PROPERTIES AND USES

Khair is a very important Indian Forest tree valued for its timber as well as other products. Following studies on properties and utilisation of khair have been carried out at Forest Research Institute, Dehra Dun (U.P.) :

PHYSICAL AND MECHANICAL PROPERTIES

Colour of heartwood of khair is distinct from sapwood . Heart wood is reddish brown to dark brown and some what lustrous. Sapwood is light yellowish white. It is some what coarse and even textured with straight to interlocked grain (Rao and Juneja, 1971).

Physical and mechanical properties of khair in green and air-dry conditions, determined by testing small clear specimens from Saharanpur (U.P.), as per standard procedure (Anon 1986) are given in Table 8.1 (Rawat and Rawat, 1960).

Table 8.1. Physical and mechanical properties of *Acacia catechu* (Khair)

Sl. No.	Properties	Seasoning conditions	
		Green	Air-dry
1	2	3	4
1.	Specific gravity (Wt.oven dry/vol.at test)	0.875	0.899
2.	Weight (kg/cu.meter)	116.9	1007
3.	Shrinkage % (green to oven dry)		
	Radial	-	2.4
	Tangential	-	4.2
4.	Static bending		
	Modulus of rupture (kg/sq.cm)	1007	1536
	Modulus of elasticity (1000 kg/sq.cm)	134.4	177.2
5.	Impact bending		
	Max.height of drop (cm) of 22.7 kg hammer	99	84
6.	Compression		
	Max.crushing stress parallel to grain (kg/sq.cm)	554	910
	Comp.stress at elastic limit perpendicular to grain	134	296
7.	Hardness (Load to embed 1.128 cm dia. ball to half its dia.)		
	Side (kg)	950	1458
	End (kg)	848	1328
8.	Shear parallel to grain		
	Max.shearing stress (kg/sq.cm)	140.9	190.9
9.	Tension perpendicular to grain		
	Max.tensile stress (kg/sq.cm)	76.6	66.4

NAIL AND SCREW HOLDING POWER

The nail and screw holding power of timber is very important property specially with regard to the use of timber in construction, packing cases and various type of joinery in which nails and screws are used. The results of studies carried out on nail and screw holding power of khair by Sekhar and Rana (1956) under different conditions of testing are given in Table 8.2.

Table 8.2. Nail and screw holding power of *Acacia catechu* (Khair) (withdrawl resistance in kg)

Condition of testing	Nail (kg)		Screw (kg)	
	Side	End	Side	End
A	220	160	537	259
B	92	121	583	359
C	309	227	546	506
Composite holding power	216		556	

A - Nail/screw driven in green condition and pulled out in green condition.
B - Nail/screw driven in green condition and pulled out in dry condition.
C - Nail/screw driven in dry condition and pulled out in dry condition.

TORSIONAL PROPERTIES

Torsional properties are useful in evaluating the warping characteristics of the timber and examining the suitability of timber for such purposes as agricultural implements, air craft construction and axles, etc. The results of studies carried out on

torsional properties of khair (Sekhar and Rawat, 1956) in green, air dry and kiln dry conditions of seasoning are given in Table 8.3.

Table 8.3. Torsional properties of *Acacia catechu* (Khair)

Seasoning condition	Properties (kg/sq.cm)		
	Torsional shear stress at elastic limit	Max. torsional stress	Torsional modulus of rigidity
Green	92	174	9980
Air dry	151	246	16560
Kiln dry	166	268	12390

SEASONING BEHAVIOUR

The timber is highly refractory and liable to end-splitting and surface cracking during seasoning. It should therefore be converted soon after the rains and stacked properly under shade, well protected from rapid drying. Seasoning of thick boards or planks should also be avoided whereever the timber is intended to be further converted into thinner section (Rao and Purkayastha, 1972). As per standard classification, it belongs to refractory class `A' timbers.

DURABILITY

The heartwood of khair is very durable. The timber is reported to be resistant to teredo and termites. `Graveyard' tests carried out at Forest Research Institute, Dehra Dun, have shown an average life of over 20 years (Purushotham et al.,1953; Trotter, 1960). As per IS : 401 (Anon., 1982), the species belongs to Durability Class I.

WORKING QUALITIES

The timber is hard to saw and machine specially if the wood is old and dry after seasoning. A heavy gauge plate saw with closely spaced teeth and shallow gullets gives the best results. Stiff tools should be used in machining and turning. The timber can be turned well and finished to an extremely smooth surface and takes polish well (Trotter, 1960; Limaye, 1954). Working qualitities of khair have been evaluated systematically under six major wood working operations namely planing, boring, mortizing, shaping, turning and sanding. The working quality index of khair works out to be 85 in term of teak taken as 100 and species is classified under group III based on its overall performance (Shukla, et al.,1991).

SUITABILITY INDICES FOR INDUSTRIAL AND ENGINEERING USES

For quick comparative assessment of any species in a quantitative manner, and for determining the suitability of the species for different engineering and industrial purposes, the suitability indices play an important role. Basic suitability indices of khair evaluated (Sekhar and Gulati, 1972) in term of teak taken as 100 are given in Table 8.4.

Table 8.4. Suitability indices of *Acacia catechu* (teak taken as 100).

Property	Value
Weight	147
Strength as a beam	128
Stiffness as a beam	119
Suitability as a post	127
Shock resisting ability	111
Retention of shape	116
Shear	155
Surface hardness	178
Refractoriness (splitting coefficient)	100

Species is classified as extremely heavy, extremely strong, tough, extremely hard and steady (Limaye, 1954).

SAFE WORKING STRESSES FOR STRUCTURAL PURPOSES

Safe working stresses for structural uses for three locations of use have also been worked out for Grade-I timber of khair after applying appropriate safety factors on the basic strength properties (Sekhar and Rajput, 1972) and the same are given in Table 8.5.

Table 8.5. Safe working stresses of *Acacia catechu* (Khair).

Properties		Working Stresses Locations		
		Inside	Outside	Wet
Modulus of elasticity (1000kg/sq.cm)		134.4	134.4	134.4
Extreme fibre stress in bending and tension (kg/sq.cm)		201	168	134
Shear (kg/sq.cm)				
(i)	Horizontal	15.5	15.5	15.5
(ii)	Along grain	22.1	22.1	22.1
Compression (kg/sq.cm)				
(i)	Parallel to grain	138	123	101
(ii)	Perpendicular to grain	77	60	49

CLASSIFICATION FOR DIFFERENT END USES

CONSTRUCTION

Construction is one of the very important uses of timber. In IS:3629 (Anon., 1986) specification for structural timber in building, 171 timbers have been classified into three groups depending on their modulus of elasticity (MOE) and modulus of rupture (MOR) in bending as follows :

Group	MOE in bending (tonne/sq.cm)	MOR in bending (kg/sq.cm)
A	Above 126	Above 900
B	Above 98 and upto 126	Above 600 upto 900
C	Above 56 and upto 98	Above 425 and upto 600

According to the above criteria, khair falls under Group A.

AGRICULTURAL IMPLEMENTS

In most of the agricultural implements, wood is used in some form or the other. 50 species of timber have been classified (Rajput, 1978) as suitable for different types of agricultural implements including bullock cart, which is important for transportation of agricultural produce. Khair is one of them, which is suitable for making plough, harrow, clod crusher, handles and carts.

TOOL HANDLES

Species for different types of tool handles have been classified in 4 groups depending on Tool Handle Figure (THF) in the following manner :

Group	THF
I	105 and above
II	90 to 104
III	75 to 89
IV	65 to 74

For evaluation of THF, the basic suitability indices like strength as a beam, suitability as a post, hardness and shock resisting ability are taken into consideration. The shock resisting ability is most important property for tool handles as handles are subjected to shock while using the tools. As THF of khair works out to be 112, it comes under Group I (Shukla and Rajput, 1981). Thus it is suitable for all types of handles for striking, scooping, cutting and shaping tools.

MINE TIMBER AND ANVIL BLOCKS

Khair is also suitable for mine timber and anvil blocks (Rajput and Shukla, 1984).

SUITABILITY FOR HARDBOARDS

Spent chips of Khair (*Acacia catechu*) have been evaluated for making hardboards (Shukla et al., 1985). the boards were found to meet the requirements of the specification for standard hardboards. Satisfactory boards were also prepared by mixing spent chips of khair and subabul in the ratio of 70:30 and 50:50.

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9

KATHA AND CUTCH

There is hardly anyone in India who has not seen or heard of katha. It constitutes an ingredient used in the preparation of pan and pan masala. Katha is purely a vegetable product occurring in the heartwood of *Acacia catechu*, popularly known as khair. In addition to katha, another marketable product called cutch is also obtained from the heartwood of khair. Even though katha can be extracted from all the three varieties of *Acacia catechu*, *Acacia catechu* proper gives the highest yield of katha; likewise, all the three varieties can yield cutch, but the highest yield of cutch is obtained from *Acacia catechuoides* (Singh, 1909). In moist forests, the size preferred for katha manufacture is 30 to 35 cm in diameter. Most of the working plans prescribe an exploitable diameter of 30 cm for bhabar and 35 cm for tarai forests of Utar Pradesh and a felling cycle varying from 10-30 years. In dry peninsular forests of Uttar Pradesh worked under selection fellings, the exploitable diameter is as low as 10 cm (Troup, 1983). Branch wood having heartwood of 2.5 cm diameter and above can also be used for the extraction of katha (Misra et. al., 1963). Freshly felled trees give higher yields of katha. The dead trees are not suitable as they contain less of katha. The trees which are gnarled and crooked are found to give better yields of katha than straight trees (Anon, 1970).

CHEMISTRY OF KATHA AND CUTCH

Chemically katha is not a single substance. The principle constituent of katha is a mixture of isomers of 5,7,3',4'-tetrahydroxyflavan-3-ols known as catechin. The catechin rich katha prepared from the heartwood of *Acacia catechu* by the cold extraction of shavings of *Acacia catechu* was found to contain a mixture of (-)-

Pl.9.1 Fig.1. Indigenous method of extraction of katha, 2. chipping of khair logs.

epicatechin (85%) and (+)-catechin. During extraction of heartwood chips with boiling water, (-)-epicatechin undergoes epimerisation and isomerization (+)-catechin.

The chemistry of cutch is lettle known. It consists of highly complex mixture of condensed tannins of catechol type.

EXTRACTION OF KATHA AND CUTCH FROM KHAIR WOOD

Though there are several factories in the couuntry which manufacture katha. Production of katha by indigenous method as a cottage industry inside the forests still continues. The main operations in the process are (1) extraction of the wood with water (2) concentration of the extract to crystallise katha (3) filtration of katha, and, (4) drying of katha.

(i) Indigenous method of extraction of katha

In the indigenous method, the first two operations are simultaneously done usually in earthen pots, arranged in parallel rows on a long shallow *bhatti*. The extraction is done in the pots in the side rows, while concentration is carried out in the central rows. The concentrate is transferred into wooden vats and the katha is allowed to crystallise. The filtration of the separated katha is effected in huge pits lined with gunny bags. The mother liquor containing valuable cutch, which has its own importance, gradually soaks into the earth, leaving katha as a semi-solid mass in the gunny bag filters. Subsequently the semi-solid katha is dried on sand beds, cut into small cubes with wooden knives and allowed to dry in shade (Pl. 9.1, Fig. 1).

(ii) Cottage scale method developed at Forest Research Institute, Dehra Dun

There is a fundamental difference between the indigenous method and the factory method. In the former, as seen above, cutch is not recovered at all, while it is isolated in full in the factory method. Further, katha produced by indigenous method is of inferior quality. But, the main disadvantages of the factory method are: (1) the factories are situated at fixed places, which are sometimes far away from khair forests and the wood has to be transported over long distances, and, (2) large capital outlay is required for the establishment of factories. It would, therefore, be best if the indigenous cottage scale method is improved so as to include advantages of the factory process. This has been achieved in the process developed by the Chemistry of Forest Products Branch of Forest Research Institute, Dehra Dun. Certain small mechanical devices and scientific control have been introduced in the indigenous method as a result of which, the yield and the quality of katha are very much improved and cutch is also recovered in full. This process is also of a shorter duration than the indigenous method (Verma et al., 1958).

The improved method runs on the same lines as the original indigenous method, the main features of the improvement being (1) the use of copper pots for extraction (2) use of open evaporating pans of copper for concentration, and (3) filtration of the separated katha using a small hand operated filter press. These measures involve some initial capital expenditure but the investment is more than compensated by (1) saving in the recurring annual expenditure on the fragile earthen pots (2) better

quality of katha produced, and (3) recovery of cutch. Details of the method are given below:

Chipping

The heartwood logs are made to stand at an incline over a solid support and chipped into small bits, approximately 20x30 mm to 25x40 mm, using a hand axe. A thatched wall is erected in a suitable direction so that flying chips strike against it and gather together (Pl. 9.1, Fig. 2).

Extraction

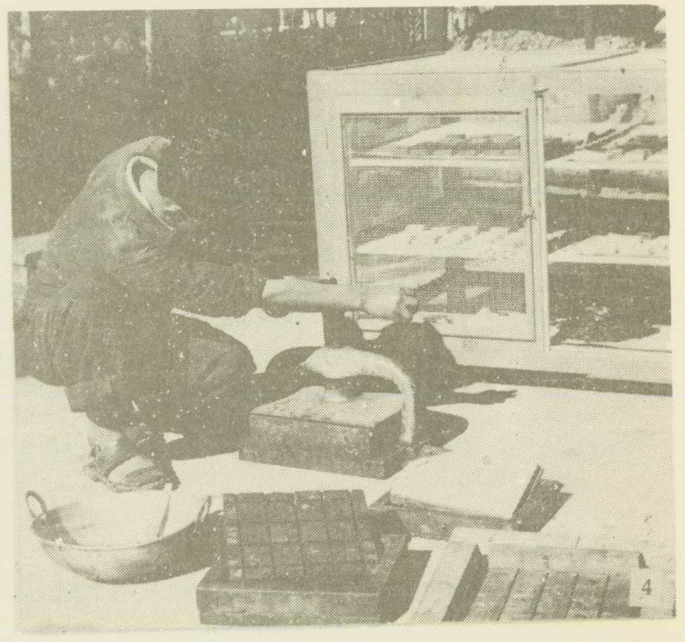
The extraction pots are made of copper sheets, 2-3 mm thick and are of about 40 litre capacity. Each extractor is provided with a protruding tap at the bottom so that the extract is easily removed. It is also fitted with a just fitting copper wire basket which serves as the hold for the chips during the extraction and facilitates their removal after the extraction. Experimentally it has been established by working with small quantities of khair wood shavings that (1) at the initial stage of extraction upto a period of 1.30 hours, the rate of extraction is high and gradually falls after that; (2) the yield of the total solids increases with increase in temperature; (3) during the first extraction itself the major portion of the soluble solids are extracted, the yields obtained in the second extraction are also appreciable and economically feasible, while further extraction will be uneconomical; (4) rise in the yield is not proportionate to the increase in the chips-water ratio, and therefore, it is enough if the quantity of water sufficient to keep the chips immersed is used for the extraction; (5) multiple contact operation gives a better recovery of the total solids than a single contact operation. In the improved indigenous method of extraction of katha, each batch of 10 kg of khair wood chips is extracted twice with potable water enough to keep the chips fully immersed (20-25 litres), the second extract being used for the first extraction of fresh chips. The extraction is carried out at boiling for 1.30 hrs; heating the extractors is done by direct fire. For heating, any type of fuel including the sapwood of the khair logs and the exhausted chips may be used (Pl. 9.2, Fig. 1).

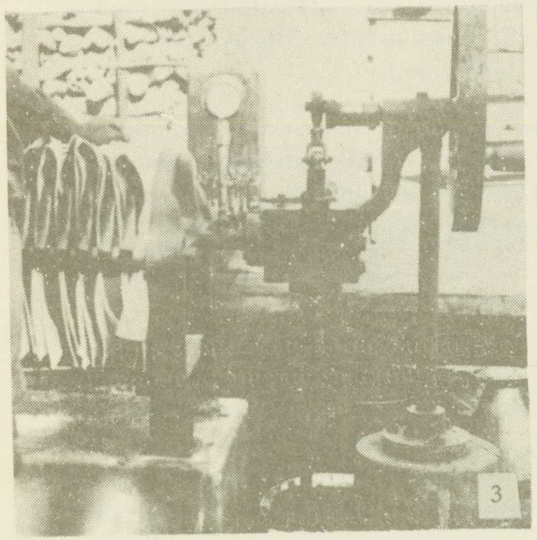
Concentration

The combined extract is concentrated at boiling temperature in a wide evaporating copper pan (1200 mm in diameter) heated by direct fire till it attains a specific gravity of 1.07 to 1.08 as read by a hydrometer. This much of concentration is enough in the cold North Indian winter climate for the katha to crystallise. In the hotter parts of India, it may be necessary to concentrate the extract a little more. Usually on leaving overnight during winter or for 2 to 3 days on warmer climates, katha crystallises out from the concentrated extract. Concentration and the crystallisation are usually carried out in the same vessel (Pl. 9.2, Fig. 2).

Filtration

Filtration of the separated katha is done in hand operated plate filter press (stainless steel or gun metal plate) using thick filter cloth in between plates. Katha is





Pl.9.2 Fig.1. Extractor 2. Concentration of the extract. 3. Filtration of katha. 4. Pressing, cutting and drying of katha.

retained on the filter cloth while the mother liquor containing cutch flows into a bucket placed below.

After opening the filter press, katha is removed from the filter cloth using wooden or nickel spatula (no iron implement to be used any where). It is macerated with fresh water and passed once again through filter press in order to remove by washing contaminating cutch. The purified katha thus obtained, is transferred into wooden frames and pressed in a hand driven screw press to squeeze out most of the remaining liquor. The resulting katha is taken out, cut into uniform blocks of 50x50 mm by means of a wire cutter made of copper (Pl. 9.2, Figs. 3&4).

The katha blocks are put in trays and dried in shade. It usually takes 4 to 5 days to dry. If the katha is pure, no discolouration takes place on drying; only when cutch is present, the cakes get tarnished. On rainy days, it is better to dry katha in an air oven heated to 40-50°C by flu gases of the extractors and concentrating pans to avoid the attack by fungus on them.

The average yield of katha is 3 to 4.5 per cent based on the weight of the heartwood.

Cutch

The mother liquor left after the filtration of katha contains practically all the cutch along with small quantity of katha. It is concentrated in the concentration pans till it becomes quite viscous. When the viscous concentrate is poured into shallow wooden vats or moulds it turns into a solid cake in course of time. The average yield of cutch is 6 to 8 per cent based on the weight of the heartwood.

Use of iron implements is not recommended for the preparation of katha and cutch as the catechu tannic acid present in the cutch forms a greenish brown compound with iron and contaminates katha and cutch. However, aluminium and stainless steel vessels can be employed in place of copper vessels (Misra and Karnik, 1964).

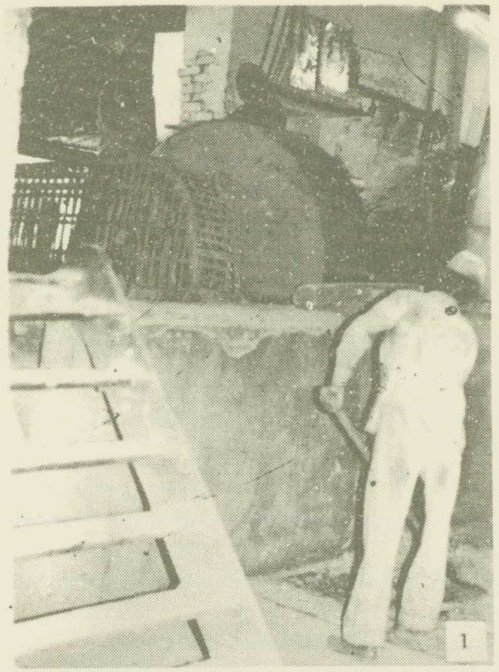
Economics of the process

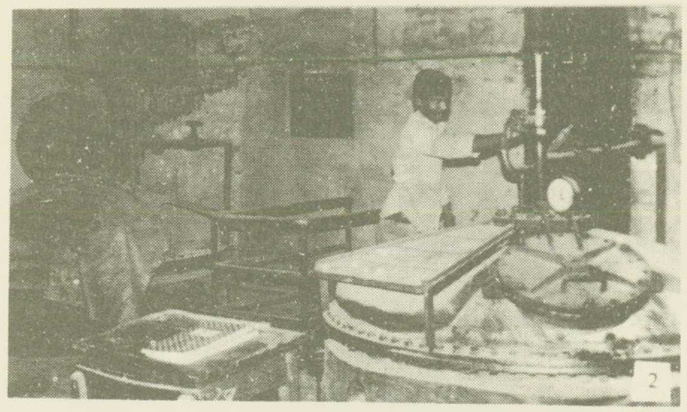
For handling 7 quintals of the heartwood per day, in three shifts of 8 hours each, 12 extractors, each taking about 10 kg of chips and 7 concentrating pans (karahis) are required. Out of these 7 pans, one is utilised exclusively for concentrating cutch liquor. In each shift there are 8 persons working, 2 on extraction and concentration, 2 on relief duty. Thus in all the three shifts, 24 people are engaged. Another set of 12 men is required for chipping the wood for 8 hours during the day to provide 7 quintals of chips required for the extraction. In each shift it is possible to carry out 2 extractions conveniently.

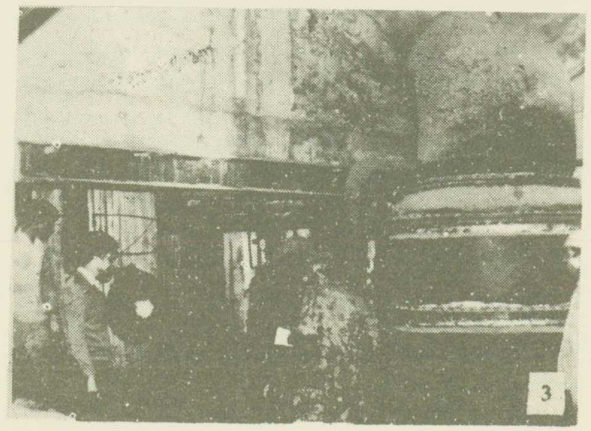
The cost of the equipments and expenditure towards the raw materials, labour etc. required for handling the above quantity of wood per day together with returns from the sale of the products are given below:

	Capital	Item	Cost in Rs.
(a)	Plant and equipment	Copper extractors (12)	7,800
		Copper pans (7)	18,200
		Copper wire baskets (12)	1,200
		G.I. sheet buckets (8)	240
		Screw press (1)	1,000
		Hand operated filter Press (1)	20,000
		Copper doies with wooden handle (4)	240
		Wooden moulds (4)	120
		Filter cloth (10 m)	250
		Copper wire cutters in wooden frames (2)	40
		Hand axes (12)	240
		Other minor items	420
		Total	49,750
		As copper vessels are costly these days, they can be replaced either by aluminium or stainless steel vessels.	
(b)	Temporary shed for storing khair wood, katha, cutch etc.		1,000
(c)	Working capital for a period of 3 months		2,60,000
Direct cost (cost of production) calculated per day			
		Khair wood (7 quintals)	2,100
		Transport to the site of bhatti	50
		Fuel for the bhatti	100
		Salary of supervising staff	25
		Labour (36 people at the rate of Rs.15 per head per day)	540
		Packing (21 kg of katha and 42 kg of cutch)	75
		Transport of the finished Products to the market	25
		Total	2,915
Indirect cost (calculated per day)			
Depreciation, loss in handling, interest on investment, other incidentals etc.			230
Total direct and indirect costs (manufacturing cost) Returns			3,145
		Sale of 21 kg of katha @ Rs.160 per kg	3,360
		Sale of 42 kg of cutch @ Rs.9 per kg.	378
		Total	3,738
		Profit	593
			(nearly 18%)

As a partial modification of the above process, extraction of katha and cutch can also be carried out in two stages (Karnik and Sharma, 1965). In this process, the heartwood is converted into shavings of about 2 mm thickness using hand planing machine. Thirty kilos of these shavings are kept immersed in water (material : water :: 1:6) for 2 hrs with thorough stirring, and the extract is collected after filtering through a muslin cloth. The residual shavings are extracted with water at boiling temperature for one and a half hours and the extract collected separately as before.







Pl.9.3 Fig. 1. Chipper and Disintegrator 2. Extractor 3. Concentrator

These extracts are concentrated separately to a density of 1.175 at 30°C transferred to a small vessel, and left overnight when katha crystallises out as brownish white crystals from both the extracts. In both the cases, crystalline mass of katha is carefully transferred to a wooden frame with canvas cloth and gently pressed in a hand driven screw press to remove as much mother liquor as possible. The semidry katha is spread uniformly and cut into tablets of 5 sq. cm size by means of a wire cutter. The tablets are initially dried in a shed and finally in an oven maintained at 40°C. In a typical experiment on the two stage extraction process for katha (Karnik et al., 1965), the first stage katha obtained by extraction at room tempperature (yield 3.19 per cent), had a catechin content of 36.7 per cent, and the second stage katha obtained by extraction with boiling water (yield 6.16 per cent) had a catechin content of 42.9 per cent. The mother liquor containing cutch of cold and hot water extracts is separately concentrated in a concentration pan and reduced to a small volume which is further evaporated in a small container to air dry solids. Katha obtained after hot extraction by two stage process is much lighter in colour and dries much faster. This modification also eliminates the filtration which is time consuming. The overall yield of katha obtained is higher than the previous method.

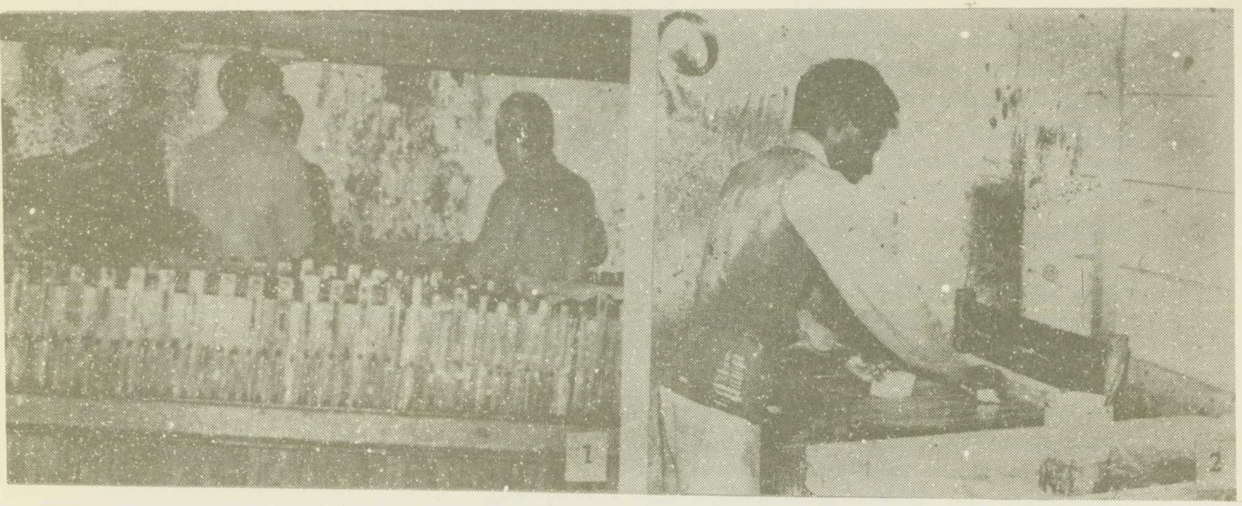
(iii) **Factory method of production of katha**

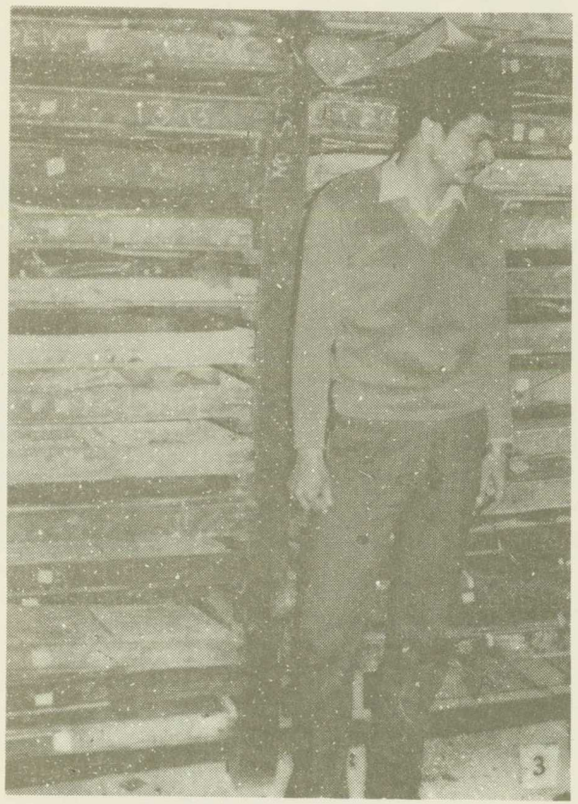
At present there are a number of factories producing katha in various parts of India. The principles involved in the factory method for the production of katha are the same as described in previous pages except that the operations are carried out by machines.

The heartwood of khair is cut into small lengths and chipped in electrically operated chippers and disintegrators to get chips of 2.5x2 cm. The bigger chips are removed by sieving (Pl. 9.3, Fig. 1).

Extraction of the khair wood chips is done either under atmospheric pressure in open vats or under pressure in autoclaves. The ratio of chips to water is 1:3. The open vats, made of wood or stainless steel, are fitted with steam coils with perforations through which steam under a pressure of 10 to 15 lbs is injected. In the autoclave, the temperature of extraction is maintained at 110-112°C by adjusting the steam pressure. Each batch of chips is extracted three times in open vats, the total duration being 12 hrs. The third extract is used to get the first extract from fresh chips. Extraction under pressure requires 11.30 to 12 hrs. Extractors are provided with outlets for the removal of exhausted chips (Pl. 9.3, Fig. 2).

The extract from the extractors is drawn into steam heated vacuum evaporators, or into a multiple effect evaporator with wire guaze sieve. The concentration is done at a low temperature under reduced pressure until the extract attains a specific gravity of 1.05 to 1.07. It is then allowed to cool to room temperature in big tanks and then to 0°C in aluminium or stainless steel containers kept inside a cold room maintained at 0°C. Katha crystallises out in 10 to 15 days time. The time required for crystallisation can be reduced by seeding the concentrate with powdered katha (Pl. 9.3, Fig. 3).





Pl.9.4 Fig.1. Filter press 2. Cutting of katha into tablets, 3. Drying of katha tablets

The removal of cutch is easily done by filtration of the crystallised katha through a hydraulic filter press of frame and plate type, provided with canvas cloth btween the plates. The filter press is made of copper, brass or stainless steel. During filtration, katha is retained in between plates and the solution of cutch flows into separate tanks (Pl. 9.4, Fig. 1).

The katha in the press is given a washing with cold water to remove the cutch solution retained by it. After removing as much of water as possible, it is cut into tablets of 5 x 5 x 0.5 cm with the help of copper or stainless steel wire cutters and then dried (Pl. 9.4, Fig. 2).

The katha tablets containing 40 to 50 per cent moisture are dried in rectangular aluminium trays kept in racks arranged in a cold room (temperature 10^{o}C) maintainec at a relative humidity of 40 to 50. When the moisture in the tablets reaches a level o 10 to 12 per cent they are ready for packing (Pl. 9.4, Fig. 3).

The cutch solution which is collected after filtration is further concentrated ir Kestner's film evaporator until it solidifies on cooling. The viscous mass while hot is poured in the wooden frames of suitable size and dried in shade. After it completely solidifies it is powdered. The average yield of katha is 3 to 4 per cent and that of cutch is 6 to 8 per cent.

Most of the factories producing katha and cutch are located in Uttar Pradesh (8 factories), Madhya Pradesh (7 factories), Bihar (5 factories) and Himachal Pradesh (1 factory). There are also six factories in Nepal situated near the Indian border which export the entire Katha produced to India. The installed capacities and annual requirement of khairwood of the factories in Uttar Pradesh and Madhya Pradesh are given in Table 9.1 and 9.2.

Table 9.1. Installed capacities and Khair wood requirement of katha factories in Uttar Pradesh

Sl No.	Name of the factory	Installed capacity (katha in quintals)	Khair wood requirement (cu m)
1.	Chandra Katha Industries, Najibabad	7800	21700
2.	Indian Wood Products, Bareilly	6000	16667
3.	Awadh Wood Products, Baharaich	9000	12000
4.	Ganesh Katha Factory, Haldwani	10500	15000
5.	Amar Shikha Wood Products, Agra	3650	10140
6.	P.K. Katha Industries, Noida	3600	10000
7.	Naresh Chandra Agarwal Katha Factory, Najibabad	3000	8300
8.	Goel Industries, Bareilly	2100	5800

Source of information : Uttar Pradesh Forest Corporation, Lucknow

Table 9.2. Insatalled capacities and Khair wood requirements of katha factories in Madhya Pradesh

Sl. No.	Name of the Factory	Installed capacity (Katha in quintals	Khair wood requirements (Trees)
1.	Sujatha Forest Products Pvt. Ltd.	900	60,000
2.	Hindustan Katha Manufacturing Co. Pvt.Ltd.	1125	20,000
3.	Sathal Katha and Chemical Pvt. Ltd.	1500	150,000
4.	Sanmathi Forest Industries Pvt. Ltd.	300	90,000
5.	Sarguja Wood Products Pvt. Ltd.	100	60,000
6.	The Gwalior Forest Products Pvt. Ltd.	450	150,000
7.	M.P. Katha Works Pvt. Ltd.	1400	90,000

The quantity of Katha and cutch produced by the factories in Uttar Pradesh (1989-90 to 1991-92) and in Bihar (1989-90 to 1993-94) are given in Table 9.3 and 9.4.

Table 9.3. Katha and Cutch Produced in Uttar Pradesh.

Sl. No.	Name of the Factories	1989-90		1990-91		1991-92	
		Katha	Cutch	Katha	Cutch	Katha	Cutch
1.	Chandra Katha Industries, Najibabad	1757.06	3348.07	1913.02	3807.78	2017.66	3360.19
2.	Indian Wood Products, Bareilly	1261.88	1783.40	1506.19	1994.75	1704.33	2530.50
3.	Awadh Wood Products, Baharaich	1085.40	1096.25	1030.20	741.75	516.00	398.00 (upto Aug.92)
4.	Ganesh Katha Factory, Haldwani	2422.85	2243.75	2194.65	2513.25	2500.00	2415.00
5.	Amar Shikha Wood Products, Agra	1526.75	3410.60	1316.80	2741.45	1225.00	2732.82
6.	P.K. Katha Industries, Noida	761.26	516.80	681.10	231.13	539.76	127.80
7.	Naresh Chandra Agarwal Factory, Najibabad	455.00	198.00	360.00	147.50	418.00	167.00
8.	Goel Industries, Bareilly	287.00	914.00	362.00	1114.00	447.00	648.00

Corresponding figures for the factories in Madhya Pradesh during 1992-93 are given below in Table 9.5.

Table 9.5. Katha and Cutch Produced in Madhya Pradesh in 1992-93

Sl.No.	Name of the factory	Katha produced (Quintals)	Cutch Produced (Quintals)
1.	Sujatha Forest Products Pvt. Ltd.	280	1184.5
2.	Hindustan Katha Manufactering company Pvt. Ltd.	223.75	671.25
3.	Sathal Katha and Chemicals Pvt. Ltd.	395	791
4.	Sanmathi Forest Industries Pvt. Ltd.	240	708
5.	Sarguja Wood Products Pvt. Ltd.	350	900
6.	The Gwalior Forest Products Pvt. Ltd.	175	600
7.	M.P. Katha Works Pvt. Ltd.	266.4	175.25

Table 9.4. Katha and cutch produced in Bihar

Sl. No.	Name of the factory	1989-90		1990-91		1991-92		1992-93		1993-94	
		Katha (Qtls)	Cutch (Qtls)	Katha (Qtls)	Cutch (Qtls)	Katha (Qtls)	Cutch (Qtls)	Katha (Qtls)	Cutch (Qtls)	Katha (Qtls)	Cutch (Qtls)
1.	Bihar Wood Products Pvt. Ltd., Hazaribagh	576	1152	691.20	1342.40	921.60	1843.20	806.40	1612.80	748.80	1497.60
2.	Bol Bam Katha Factory, Fatehpur, Gaya	-	-	-	-	504	1008	518.40	1036.80	576	1152
3.	Betiah Katha Factory, Pvt. Ltd., Betiah	-	-	-	-	201.6	403.2	518.4	1036.8	345.6	691.20
4.	Gopal Katha Industries, Pvt. Ltd., Gaya	115.20	230.40	144.00	288.00	----------Closed----------					
5.	Kumar Katha Co. Ltd., Gaya	230.40	460.80	288.00	576.00	----------Closed----------					

It can be seen that the production is far below the installed capacities mainly because of the inadequate supply of khair wood. This is mainly due to the decrease in the availability of tree in the forests and plantation resulting from the over exploitation in the past which was not compensated by plantations. Restrictions imposed on felling of the trees in the forests due to various forest policies are also responsible for inadequate supply of the raw material. The trees allotted to katha manufacturers is barely 45 to 55 per cent of the actual requirement in Madhya Pradesh.

In Uttar Pradesh factories get the required wood from other sources as well, which is evident from Table 9.6.

Table 9.6. Requirement of Khair wood in Uttar Pradesh.

Sl.	Name of the Factories	Source of supply of khair wood							
		1988-89		1989-90		1990-91		1991-92	
		Forest		Forest		Forest		Forest	
		Corpo-ration	Other source	Corpo-ration	Other source	Corpo-ration	Other source	Corpo-ration	Other source
1.	Chandra Katha Industries, Najibabad	1256	-	1418	5457	2196	5170	-	6081
2.	Indian Wood Products, Bareilly	1885	-	2126	2024	3292	1320	-	4836
3.	Awadh Wood Products, Baharaich	903	-	1019	556	1578	624	-	652
4.	Ganesh Katha Factory, Haldwani	1256	-	1418	4867	2196	5225	-	6894
5.	Amar Shikha Wood Products, Agra	1021	-	1152	4024	1784	2710	-	4393
6.	P.K. Katha Industries, Noida	510	-	576	588	892	23	-	636
7.	Naresh Chandra Agarwal Factory, Najibabad	393	-	443	357	686	-	-	855
8.	Goel Industries, Bareilly	628	-	709	352	1098	169	-	1578

Source of information : Uttar Pradesh Forest Corporation, Lucknow.

Quantity of Khair wood required and Khair wood obtained by the factories in Bihar are given in Table 9.7.

Table 9.7. Khair wood required and khair wood obtained by factories in Bihar

Sl. No.	Name of the factory	Khair wood required (m^3)	Khair wood obtained (m^3) (1989-90 to 1993-94)
1.	Bihar Wood Products Pvt. Ltd., Hazaribagh	8,000	2,000 - 3,200
2.	Bol Bam Katha Factory, Fatehpur, Gaya	7,000	1,750 - 2,000
3.	Betiah Katha Factory Pvt. Ltd., Betiah	10,000	700 - 1,800
4.	Gopal Katha Industries, Pvt. Ltd., Gaya	5,000	400 - 500
5.	Kumar Katha Co. Ltd., Gaya	6,000	800 - 1,000

It can be seen that the khair wood available to the factories is far below their requirement.

Katha industry in India also faces the problem of increase in price for the raw material in addition to the dwindling supplies. In 1985-86, the average price for khair wood allotted to factories by Uttar Pradesh Van Nigam was Rs.3008 per cubic metre which was increased to Rs.7,268/- in 1991-92 and Rs.9,505/- during 1992-93. The price of katha depends on the quality. The best katha fetches as high a price of Rs.300/- per

Kg. while the price of cutch is about Rs.15/- per Kg. The industry also faces competition from katha brought into India from Nepal.

In Bihar, the escalation in the price of khair wood allotted by the forest department to katha factories was from Rs.2533.95 in 1989-90 to 3525.00 in 1992-93 for 30-45 cm girth class, from Rs.6352.00 in 1989-90 to Rs.7850.00 in 1992-93 for 45-60 cm girth class, from Rs. 7562.50 in 1989-90 to Rs.11625.00 in 1992-93 for 60-90 cm girth class and from Rs.8470.00 in 1989-90 to Rs.12,500.00 in 1992-93 for girth class above 90 cm.

USES AND MARKETING

Katha is reported to possess cooling and digestive properties, and is used in the treatment of throat, mouth and gum infections. Externally it is used as an application for ulcers, boils and skin eruptions. Katha is also an ingredient of a number of Ayurvedic and Unani medicines.

In the trade the name katha is used for all varieties of solidified aqueous extract obtained from the heartwood of *Acacia catechu*. It is normally sold in the form of tablets of about 5 cm square of varying thickness. Different grades of katha are available in the market. Each factory has its own standards for grading which are generally based on external appearance and other factors. Two criteria which determine the market value of katha are colour and freedom from impurities. Light coloured (nearly white) katha fetches a higher price than dark coloured ones. Good grade katha when broken open into two halves known as "Tod" in trade, should have smooth uniform surfaces with pale yellow colour. Poor qualities of katha show uniform surface on breaking and the surface is blackish-white in colour. Indigenous katha shows alternate layers of pale and dark brown. The catechins absorb as much as 20 times their weight of water and swell. When katha is boiled with 4 to 5 times its weight of water and allowed to cool for 6 to 8 hours it forms a thick paste. The semisolid paste obtained after removal of water soluble tannins by filtration is known as "Londi" in pan trade. Good quality katha gives as high as 3 times its weight of Londi while the inferior one gives its own weight or even less (Dhungat, 1982).

The Bureau of Indian Standards have prescribed specificationss for katha in IS:4359-1967 which are given below:

	Grade I	Grade II
Loss on drying	15	15
Catechin content (% weight)	55	40
Extractives in cold water (% weight on dry basis)	45	60
Matter insoluble in rectified spirit (% weight, maximum)	25	25
Insolubles in boiling water (% weight, maximum)	3	6
Total ash (% weight)	1.5	4

Cutch is at times used as a cheap substitute for katha by some villagers and tribals. It is also used as a natural dye which produces browns and olives with different mordants. It is used as a protective agent to fishing nets and sails which are

exposed to sea water and for colouring certain varieties of chewing tobacco, mail bags etc. Even though it contains about 60 per cent tannins, it is seldom used as self tanning material because it has poor penetrating qualities and produces dark coloured brittle leather. In combination with wattle it is used for producing heavy leathers. A large quantity of cutch is used in oil-well drilling for reducing the viscosity of mud. Generally cutch is packed in wooden cases (50 kg each) or in hessian bags (40 kg each). It is also packed in various forms and shapes as desired by the customer and also marketted in the pulverised form. The Bureau of Indian Standards has prescribed the following specifications for cutch in IS:3967-1975 which are given below:

Moisture, per cent by mass, max.	14
Tannins, per cent by mass, min.	60
Non-tannins, per cent by mass, max.	34
Insolubles, per cent by mass, max.	1.7
Iron, mg per 100 g, max.	5
Copper, mg per 100 g, max	5
pH (Analytical solution) min.	4.0
Colour Red, max.	8.0
Yellow/red, min.	1.2

CATECHIN

Catechin is an essential constituent of katha. The value of khair as asource material for kaha depends on its catechin content which also determines the quality of katha. Catechin is soluble in hot water but insoluble in cold water whereas cutch is freely soluble in cold water. Several methods are available for the estimation of catechin. Out of them, emulsification of catechin with methanol followed by extraction with catechin mixture (mixture of carbon disulphide and ether in the ratio 1:4) gives more reliable values. In this method (Karnik and Sharma, 1964) a known quantity of the sample (0.5 g) is shaken with methanol (2.5 ml) so as to form a slurry. The methanol is evaporated on a water bath. Catechin mixture (50 ml) is added and refluxed for 1/2 hr. The mixture is cooled and allowed to settle. It is filtered into a tared beaker by decantation through a filter paper. The process of extraction is repeated twice, each time using 50 ml of the mixture. The residue after the third extraction is washed with 20 ml of the mixtue and the solvent is distilled off from the combined filtrate and the washings. The percentage of the dry residue obtained gives the percentage of catechin in the sample. In a tree, the distribution of catechin is found to vary as indicated in the attached figure (Misra and Sharma, 1963).

CATECHIN RICH KATHA

A solvent extraction process was developed at Forest Research Institute for extracting catechin rich katha in about 5 per cent yield from the heartwood of *Acacia catechu* (Indian patent, 91662). In this process, the heartwood is converted into shavings, chips or dust. The converted material is extracted with 90 per cent ethyl alcohol (wood:alcohol :: 1:8) at room temperature in a copper or aluminium or stainless steel extractor. Two extractions of 2 to 3 hours are made with constant stirring. The

second extract can be used for the first extaction of the fresh chips. The extracts after filtration through muslin, are concentrated in a evaporator under vacuum to a specific gravity of about 1.1 and then left in the open vessel for crystallisation. After complete crystallisation, the mass is filtered through a filter press. A wash of cold water is given to remove cutch. The catechin rich katha is taken out from the press and is pressed again in a screw press of wooden frame having a thick canvas cloth. The pressed material is dried under shade at room temperature. The exhausted shavings are boiled with water to extract the cutch present in them. The extract and the mother liquor after the removal of catechin rich katha, are mixed together and concentrated in an open pan to get cutch as described in the previous pages.

The catechin rich katha obtained is a needle shaped crystalline substance of greyish white colour with m.p. 230-235°C, $[\alpha]_D^{28}$-32.0(c, 0.5, ethyl alcohol), -50.0 (c, 0.5, acetone), and ash content of about 0.22 per cent. It is odourless and has a sweetish taste. It is soluble in hot water giving a reddish brown solution, the intensity of colour varying with the concentration. It contains (-)-epicatechin (85.0 per cent) and (+)-catechin (8 per cent) with traces of (+)-epicatechin. It was found suitable for pharmaceutical preparations. It is reported that (-)-epicatechin has vitamin p activity by virtue of which it can prevent certain diseases relating to blood capillaries. Shades of colour obtained with catechin are light brown in water, and, bright pink in alcoholic solution. The colour is fast to light. As catechin is also not poisonous, it can safely be used as a food colour (Karnik et. al., 1973).

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