

Agroforestry Model for Assam



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HORTICULTURAL RESEARCH STATION
Assam Agricultural University, Kahikuchi, Guwahati-17



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PREFACE

Agroforestry is an effective land use system contributing enormously towards food, nutritional and environmental security. In more than 140 countries worldwide it has been recognized as an important tool to ensure livelihood, food, nutrition, fodder, energy as well as increased income to farmers; arresting soil degradation and to mitigate as well as adopt the adverse effects of climate change. Its relevance is increased day by day with the shrinkage of fertile land due to population explosion and acceleration of soil degradation due to intensive cultivation practices.

Farmers of North East India, like any other part of the country, have the distinction of using agroforestry system in numerous forms since time immemorial. Wide variation in agro-climatic, agro-ecological and socio-economic characteristics in the region gives rise to popularity of various agroforestry systems traditionally. Baree – the home garden known in the area is the most popular agroforestry system throughout the state of Assam; on the contrary, shifting cultivation is still popular in the hill districts of Assam and neighbouring hill states.

Since 1983, a tremendous boost has been witnessed with regard to research information and extension activities on agroforestry throughout the country. However, lack of easy access to credible scientific knowledge with respect to the most suitable site specific agroforestry systems in the region is one of the prime hindrances for farmers and promoters of agroforestry. Therefore, identification of agroforestry models for prominent tree species is of utmost importance at the moment.

Considering all these, it has been tried to write the book on fourteen prominent tree species of the region. Models have been identified based on research activities on AICRP on Agroforestry Project, survey of traditional agroforestry systems in the state and interaction with tree growers. Hope the book will immensely help the practitioners and promoters of agroforestry which will ultimately serve the purpose of livelihood security, nutritional security, environmental protection and also help to double the income of the common farmers in this region. The book is tried to be written in farmer friendly manner.

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Agaru (*Aquilaria malaccensis* Lam.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture, Aqua-Silviculture
Common Name:	Eagle wood tree, Agar tree
Trade name:	Agar tree
Assamese name:	Agaru, Sanchi
Family:	Thymelaeaceae

Introduction

Aquilaria malaccensis Lam. is one of the most important and high valued aromatic tree. This tree is renowned in Assam as the symbol of knowledge as all the writings of ancient Assam, used *Sanchi-pat* i.e. the bark of the tree for writing purposes. Besides, aromatic substance the Agaru has been used since time immemorial. At present, the species is famous for its aromatic products – Agarwood and Agar-oil; both are utilized as excellent quality perfumery raw materials. In natural condition, all the agar trees do not produce these products; heartwood of agar tree produces resinous dark brown product due to self defense mechanism only when it is infected by the fungi *Phialophora parasitica* during early growth stage of the tree. This fungal attack takes place at the site of injury caused by the attack of trunk root beetle or Ambrosia beetle (*Dinoplatypus chevrolati*).

Habit and Habitat

Agaru is a medium size evergreen and heliotropic tree usually 18 - 20 m tall with 1.5-2.5 m girth, straight & fluted bole and medium crown. It prefers high humid subtropical climate with annual rainfall of 1800-3500 mm. It grows from sea level up to 500 m above msl. The species grow well in varied soils; however well drained deep sandy loam to loam soil rich in organic matter is mostly preferred. It grows luxuriantly in hill slopes in acidic soil under forest environment.

Silvicultural Character

Agaru is a light demander species. It is sensitive to excessive drought. The species coppices and pollards well up to middle age (up to 10-15 years). Leaves are commonly browsed by cattle or goats.

Distribution

Agaru is distributed in the Eastern Himalayas of India, Bangladesh, Bhutan, Myanmar and sporadically in South East Asian countries. Within India, it has been recorded in Assam, Arunachal Pradesh, Nagaland, Meghalaya, Manipur and Tripura. However, due to large scale and unsystematic commercial exploitation, Agar tree is now almost completely extinct in its natural habitat except in limited areas of Bhutan, Arunachal Pradesh and Nagaland.

In Assam, this tree was once found naturally in abundance in old Sivasagar district and also sporadically in other districts of the Upper Brahmaputra Valley Zone and Arunachal Pradesh border areas of Darrang and Sonitpur districts of North Bank Plain Zone. Within Assam in natural forest vegetation Agar tree is now almost extinct. However, due to commercial importance it is now extensively cultivated in the districts of Golaghat, Jorhat, Sivsagar, Charaideu, Tinsukia, Nagaon, Hojai, Goalpara, Dhubri, Karimganj and Hailakandi; besides, it has also been grown in some pockets of the neighbouring states.

Phenology

Leaves are alternate 0.5-10 cm long, oblong, lanceolate or elliptic, caudate, acuminate and glabrous with slender nerves. Venation is parallel and petiole is 0.3-0.5 cm long. Flowers are white in colour, bisexual, pedicellate, in both axillary and terminal umbellate cymes, shortly peduncled, perianth, companulate, lobes 5 spreading and densely pilose. Pedicels is 0.5-0.8 cm long slender, perianth 1.3-1.5 cm long, silky, densely villous, connate at base remains persistent in fruit. Stamens are 10, anther 10 with sub-sessile disc. Ovary is sub-sessile, villous and two celled. Stigma is large and sub-sessile. Fruit is capsular, 3-5 cm long, ovoid, pericarp coriaceous and densely tomentose. Seeds are ovoid with a long tail.

Propagation Technology

Natural propagation: Seed, coppice

Artificial Propagation: Seed, entire transplanting and coppice

Nursery technology

Seed selection: Two variants of Agararu are observed in Assam - '*Jati Sanchi*' and '*Bhola Sanchi*'. Seeds from only *Jati Sanchi* should be selected as it yields more agar products than *Bhola Sanchi*. Seed ripens in Jun-Jul; however, in some trees viable seed can be harvested during late Sep to 1st week of Oct. As the seed has short viability (7-10 days) therefore, seed should be sown in nursery immediately after harvesting.

Pre-treatment: No pre-treatment of seed is required; however, dipping in water at room temperature enhances germination percentage.

Seed sowing: Seedling can directly be raised in raised bed. Alternatively, seedling can be germinated in sand bed followed by transferring to poly bag of size 5 cm x 10 cm after 25 days of emergence. Seedlings in poly bag should be under temporary shade. Shifting of bags should be done at monthly interval to prevent the seedlings from penetration of roots to the soil. Light irrigation should be provided to the seedlings after the shifting.

Cultural Operation

Land preparation: Land should be prepared by ploughing and harrowing after clearing of bushes and shrubs, if any.



Agaru in Barea

Spacing: Spacing of 2.5 m x 2.5 m is the ideal initial spacing for mono crop or boundary plantation of Agar tree. When the planting is done with some other tree species the spacing should be maintained accordingly.

Pit size: The planting of the saplings is done in well prepared pits of size 50 cm x 50 cm x 50 cm.

Planting: The best time of planting is Apr-Jun; however, it may be continued up to Sep depending upon soil temperature and rainfall. One seedling per pit should be planted. Planting should preferably be done at evening time or during cloudy weather without root distortion. To keep the seedlings in upright position staking should be done; besides, the soil around the bases of the plant should be firmly consolidated.

Manure and Fertilizer application: Well decomposed cow dung/FYM @ 10 to 15 kg/pit should be applied and well mixed with soil prior to planting. The rhizosphere of agar tree (0 to

45 cm) exhibit a higher rate of microbial population when beneficial microbe mediated organic manures is used.

N, P₂O₅ and K₂O at the ratio of 10:10:4 is applied in 2nd year @ 200 g/tree (83 g N, 83 g P₂O₅ and 33 g K₂O) followed by 400 g/tree (166 g N, 166 g P₂O₅ and 66 g K₂O) and 500 g/tree (208 g N, 208 g P₂O₅ and 83 g K₂O), respectively in 3rd and 4th year. Fertilizer should preferably be applied in two splits, one at onset of monsoon and another at cessation of monsoon. Fertilizer should be applied along with decomposed cow dung/ FYM. From 6-7 year onwards, an additional dose of nitrogenous fertilizer @ 400-500 g/tree/year may be applied in two splits during pre and post monsoon period. This will help keeping the tree wood soft, with higher content of cell sap enabling easy insect boring followed by fungal infection and spread of infected area over a larger wood volume.



Agaru block plantation

Augmentation of oil formation

Cultural treatment: Formation of agar wood is initiated traditionally by creation of open wound on the trunk of agar tree. It is a common practice for early infection. This is done just before spring season by giving deep slanting cut in tree trunk with a sharp knife (*Dao*). Injuries facilitate infection and also to push the tree to undergo a stress condition; it helps to spread the infection. Under favourable climatic conditions, this practice yields better result where beneficial microbial population in soil is sufficient. These cut injuries serve the initial sites of fungal infection. The distillable wood product obtained out of this treatment for oil extraction is locally known as '*Ghap mal*'. A 20-year old tree that may produce only 5-10 kg of distillable wood without any treatment, however, mechanical injuries result more than 30 kg in about 2 years.

In artificial inoculation method 6-8 holes of 1.0-1.5 cm diameter are made at the trunk of tree at the distance of 30 cm, followed by inserting suitable inoculums and the holes are closed with cotton for 6-7 months. After that holes are reopened to provide suitable environment for fungal activities. In this method, essential oil production starts after 9-10 months. Works on commercialization of this method are in progress.

Detection of productive trees: Since infected agarwood is located deep within the trunk, its detection from outer appearance is not easy. Generally, such trees are distinguished by certain external symptoms whether or not the tree harbours precious agar oil or agaru deposits. External symptoms are (a) a poor crown, decayed branches, and uneven bole, (b) swelling or depressions and cankers on the bole, (c) the appearance of hordes of ants in the fissures, (d) a distinctly yellowish to brownish tinge in the wood under the outer bark and (e) signs of ill-health partially a die-back symptom of the top and outer branches and a yellow tint to the woody tissues.

The visible wounds, cankers on the bole, stem distortions, smaller leaves and the rotten branches provide evidences of agaru deposits within a tree. Wood assumes distinctly yellowish tinge when agar formation takes place. The normal wood in the healthy trees is of pale brown buff colour. The change can be observed by removing the bark of the tree. Sometimes screw augers are driven inside at various depth and samples are drawn for examination. The disease or the fungal infection usually takes some time to make it manifest, hence agaru is hardly found in young tree.

Tending Operation

Weeding: During monsoon 2 weeding are required in 1st and 2nd year

Soil working: Soil working to a radius of 50 cm around tree is to be done once in 3 to 4 months. Manure and fertilizer application should also be followed by this operation preferably twice in a year, before and after monsoon from 2nd year onwards.

Fencing: Agar seedling is browsed by goat or cattle. Therefore, the plant requires protection for at least 4 to 5 years from farm animals. Trenching around the plantation has also given good protection.

Irrigation: 1-2 irrigations are necessary in first and second year during prolonged drought period.

Lopping: In small scale tea garden Agarum is grown extensively as shade tree or as boundary plantation. In such cases, regular lopping of branches above tea bushes is required.

Thinning: When Agarum is planted along with other tree species or with intercrops at a wide spacing thinning is not required. On the other hand, in closure spacing about 40-50 percent of the trees should be thinned out in 2-3 phases within 12th year of plantation. This is important for obtaining a substantial mid-term income and better growth and development of the remaining trees.

Coppicing: Coppiced shoots of an infected tree has higher probability for heavy infestation of trunk root borer and fungal infection. Therefore, coppicing of infected tree is one of the most important practices for agar tree plantation. Coppicing during 10-15 years of age results in fast growth of new shoots and attain harvestable stage within next 10-15 years with higher amount of distillable wood. Best results are obtained during Mar-May. Coppicing during monsoon and winter months gives poor results.

Rotation: A profitable plantation of agar tree is 15-year cycle or more. Agar-attar of low quality (*Boya oil*) is found from the short cycle plantation.

Tree Protection

Insect-pest: In Agarum plantation generally no serious insect pests and diseases have been observed. However, *Hoertia viressoides* a leaf eating caterpillar is considered to be the most destructive pest causing damage by complete defoliation of agar trees and has become a real menace to the plantations in NE Region. The intensity of attack is more in the trees grown in open condition than under shade. During Mar/Apr (dry season) the infestation is comparatively higher than Jul/Aug (rainy season). The pest found to cause defoliation twice in a year in May/Jun and Aug/Sep. The intensity of attack is more severe during May/Jun and can cause death of well grown trees due to complete defoliation.

Management: (a) Hand collection of leaf eating caterpillar and destruction of early instars of caterpillar clusters, (b) at severe attack spraying of contact insecticides like Quinalphos 25 EC @ 2ml/lit of water at 10-15 days interval, (c) severe infected tree should be given an extra dose of nitrogen.

Orientation

Boundary plantation: Agarum is suitable for growing in field boundaries and for dividing whole plot into sub plots. It is also grown in border of garden, school compound, office compound, parks, residential sites and border of small tea garden.

Pond dyke & road side plantation: Agarum can be successfully grown by strip planting along bank of tank, pond, canal and road.

Homestead plantation: In homestead garden Agarum is grown along with areca nut, coconut, banana, bamboo etc.

Block plantation: Agarum plantation is also done in block. Different intercrops are grown during early growth stages.

Suitable Intercrop

Any crop can be grown when agar tree is planted in boundary. In block plantation of Agar, vegetables/pulses/fruits or medicinal and aromatic crops like Patchouli (*Pogostemon cablin*), Sugandh mantri (*Homalomena aromatica*), Kalmegh (*Andrographis paniculata*), Gathion (*Kaempferia galanga*), pineapple, etc. can be cultivated during first 3-5 years of plantation. Ginger/turmeric may also be planted during initial 2 to 3 years. In later stages shade tolerant medicinal plant like Sarpagandha (*Rouvolfia serpentina*), Pipali (*Piper longum*) and Kalmegh can be grown successfully depending on tree population and land situation. In homestead Agar can also be grown along with areca nut, coconut, banana, etc.

Yield/Annual Return including Tree Productivity

Harvesting: The age, growth rates and /or wood volume or physiological maturity do not govern the harvesting age of Agar for commercial purpose. Only the infected trees which produce agarwood and oil are harvested; the growth of these trees is often arrested due to physiological imbalance. Such trees exhibit considerable sign of infection and may be considered for harvesting. The healthy trees are left to undergo stresses or subject to infection either naturally or artificially to induce oil formation. Harvesting is done on selection basis and continues for a longer period from a plantation raised at the same time. Although harvesting of agar trees for oil extraction as well as for *agaru* is done almost throughout the year, the best time is during Feb-May (Summer season) or dry season when the plants remain almost dormant or less active. During this period maximum concentration of oil with less waxy substances is obtained. Bio-molecule concentration is more when stress is higher. The extracted oil during dry season possesses the finest odour as compared to that obtained during rainy season when the plant remains active in growth.

Post-harvest processing: The harvested tree is processed for two products: (a) *agaru* or agarwood that is used as incense and (b) essential oil or agar oil or agar attar. A large lesion impregnated heavily with oleoresin is separated from the healthy part of wood and is marketed as *agaru*. Market value of agarwood varies depending on its quality which is determined on the basis of its colour, weight, fragrance, shape and extent of accumulation of oleoresin. After felling a tree, the smaller branches are removed. Then the tree is cut into logs (pieces of 2-2.5 ft.). Thereafter, the logs split to separate out the infected and non-infected woods. The agar wood of any grade, if detected, is first separated out with the help of indigenous tool like hacksaw blade and ‘*Batali*’ and graded them based on the extent of infection and characteristics. These are then dried, cleaned by removing the white woody portions as far as practicable, polished and graded for marketing. *Agaru* is obtained from older trees while oil is distilled from old as well as younger trees.

Agar oil is obtained by steam distillation of harvested wood chips or coarse powder in special type of Stainless Steel made distillation unit. Distillation is continued for 5-10 days.

Yield: The yield of commercial product of Agarum is not uniform in all productive trees. It varies greatly and is almost unpredictable. After 10 years of planting with intensive management, each infected tree may yield about 30-40 kg distillable wood product for oil extraction, depending on infection intensity. Therefore, quality of oil varies depending on types of wood used for distillation.

Economics

Estimated economics of cultivation per hectare (Source: Ahmed ,M and Barua,I.C. 2013 Package of Practices for Medicinal Plants of Assam.Publ.by Directorate of Horticulture and Food Processing,Khanapara,Guwahati-22)

Expenditure	1 st yr.	2 nd yr.	3 rd yr.	4 th yr.	5 th yr.	6-8 th yr.	9-15 th yr.
Cost of fencing & repair	15,000	-	3,000	-	5,000	5,000	7,000
Land preparation	5,000	-	-	-	-	-	-
Pit making 1700xRs.2/pit	3,400	-	-	-	-	-	-
Cost of sapling 1700 x Rs. 5/sapling	85,000	-	-	-	-	-	-
Cost of planting Rs. 2/plant	3,400	-	-	-	-	-	-
Compost	9,000	8,000	8,000	8,000	8,000	-	-
Fertilizer	-	5,000	6,000	8,000	9,000	-	-
Cost of application Rs. 2/plant	3,400	3,400	3,400	3,400	3,400	-	-
After care/year	5,000	5,000	5,000	5,000	6,000	20,000	30,000
Misc.	1,300	1,600	1,600	1,600	1,500	30,000	7,000
Total	54,000	23,000	27,000	27,000	33,000	1,58,000	82,000

Total expenditure - up to 8th year = Rs. 3, 22,000/ha
 Next 9-15 years = Rs. 82,000/ha
 Total = Rs. 4, 04,000/ha

Anticipated yield and income: Assuming 1500 nos. of trees at 8th year out of total, we may harvest 40 % of the selected trees i.e. 600 nos. with a view to thin out the population for remaining 900 trees for further growth and development and also to generate an interim income. The final harvesting of 900 trees would be done at 15 the year.

Assumptions: Yield of distillable wood (low quality *Dum* or *Boya*) from 8-10 years old tree 20 kg/tree @ Rs. 10/kg; yield of *Dum* at 15th year 50 kg/tree @ Rs. 50/kg; yield of *Kalagachi/Batali mal* (agarwood) 0.5 kg/tree @ Rs. 2000/kg from about 500 trees.

Return

Gross return: (a) at 8-10 years *Dum* 600 x 20 x 10 = Rs. 1, 20,000/ha
 (b) at final harvest *Dum* 900 x 50 x 50 = Rs. 22,50,000/ha
 (c) Agarwood 500 x 0.5 x 2000 = Rs. 5,00,000/ha

	Total	= Rs. 28, 70,000/ha
Net return: (Rs. 28, 70,000 – Rs. 4, 04,000)		= Rs. 24, 66,000/ha

From an established plantation thus a net income of Rs. 25-30 lakh/ha after 15 years may be generated giving an average of Rs. 1, 96,400/year/ha. Intercropping in the early stages of growth can generate extra income.

Use

Agar-wood (*agaru*) and agar-oil is used in luxury perfumery. Agar wood is an astringent, stimulant, tonic herb that relieves spasms, especially of the digestive and respiratory systems, and lowers fevers. The incense is used against cancer, thyroid gland, abdominal complaints, rheumatism, asthma, smallpox, etc. The incense is also used as an insect repellent. It is highly valued for its strength and durability and is made into cloth and ropes. The timber of disease free trees is suitable for making boxes, light indoor construction and veneer. In Malaysia the resin is used to flavour curries.

Environmental Benefit

Intervention of Agri-Silviculture and Agri-Horticulture system helps in recycling of nutrients and improving soil health. It is an ideal choice for large-scale afforestation programmes in congenial areas for management of soil erosion by providing green cover.

Way Forward

Agaru based Agri-silviculture or Horti-silviculture system has tremendous scope especially in the foot hill region and flood free areas. It is potential to grow in homestead as it is highly remunerative tree crop.

Baghnala (*Litsea glutinosa* (Lour) C.B.Rob.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Indian Laurel
Trade Name:	Maidalakri
Assamese Name:	Baghnala
Family:	Lauraceae

Introduction

Litsea glutinosa (Lour) C.B.Rob. is an evergreen tree of medium size which grows to the height of about 6-10 m.

Habit and Habitat

Baghnala grows best in hot and humid climate in subtropical regions with annual rainfall of 2500 mm; average annual temperature requirement is 19-21⁰C with 7-8 months > 20⁰C. It is usually found up to the elevation of 1000 m above msl. The plant is grown in alluvial or red soil having pH 5.0-7.0; minimum soil depth requirement is 0.6 m. Soil should be well drained.

Silvicultural Characters

Baghnala is a light demanding species requiring moderate soil moisture. It does coppice fairly. Leaves are commonly damaged and browsed by domestic animals.

Distribution

Baghnala is native to India and has extended to Indo-China, Malaysia and northern Australia. In India, it is found naturally in mixed primary and secondary forest areas; besides, this species occurs in areas under plantation forest, coastal area, agricultural land and even in urban area. In many locations it colonizes all open areas including shaded areas and even in undisturbed forest. In the North Eastern India, Indian laurel is found in thickets especially under sub-tropical regions. Highland, hilly and flat topographical situation are suitable for the species. In such areas, it grows abundantly in secondary forest or rehabilitated forest after shifting cultivation.

Phenology

Indian laurel is an evergreen tree with about 2-2.5 cm thick bark, brown in colour; branchlets is slender, stiff, minutely tomentose towards apex. Leaves simple, pilose when young; lamina 6-23.5 cm x 3-10 cm, elliptic, elliptic-oblong or obovate, base acute, apex acute, obtuse or acuminate, margin entire, glabrous above, grey-pubescent beneath, chartaceous; lateral veins 7-12 pairs, pinnate, prominent, intercostae reticulate. Flowers unisexual, 5-6 mm across, yellow, in many flowered umbels; peduncle upto 5 mm long, slender, densely pilose; perianth short; tube

silky, funnel shaped, segments 0; stamens 9-12, all fertile, in 4 rows; filaments 2 mm, very hairy; fourth series glandular, glands sessile, orbicular; ovary half interior, 1 mm long; style 1.5 mm, stigma dilated, irregularly lobed; staminoids 9-12, to 2.5 mm. Flower in May to June. Fruit berry, 6-10 mm across, depressed, globose, purple, on flat disc, fruit stalk is 3-6 mm, slightly thickened at the top. When ripe fruit is blackish violet covered with white powder. One kilogram seed contains 2,500-3,000 number seeds.



Baghnala tree

Propagation Technology

Natural propagation: Seed, coppice

Artificial Propagation: Seeds, Coppice

Nursery Technology

Seed selection: Ripe fruits are collected in Oct-Nov and rinsed to remove the fruit coat. The seeds are sown in moist sand. Seeds sprout after 10-15 days and are then planted in poly bag of size 20 x 10 cm. Partial shade (40 %) is provided for the seedlings. Germination is not very rapid; approximately 85 % germination is achieved in 15-45 days.

Cultural Operation

Land preparation: Land should be prepared after clearing of bushes and shrubs, if any. Areas having gentle slope can be leveled with minor land shaping and providing suitable type of bunds across the slope.

Spacing: For mono crop, spacing is 3 m x 3 m and mixed crop wider spacing is adopted depending upon the species for mixing.

Pit size: The planting of the saplings is done in well prepared pits of size 45 cm x 45 cm x 45 cm in deep soil and 60 cm x 60 cm x 60 cm in shallow soil.

Planting time and method: Ideal planting time is May-Jun. One sapling/pit should be planted.

Manure Application: For each pit, about 5 kg of well decomposed FYM or compost is applied at the time of plantation. Well decomposed cow dung/FYM @ 10 to 15 kg/tree should be applied from 2nd year onwards.

Tending Operation

Weeding: For initial 2 years 2-3 weeding is required.

Irrigation: Irrigation is favourable during drought and winter season.

Lopping: Lopping of branches is needed and leaf can be utilized as fodder.

Rotation: Usually the rotation is done for 10-15 years.

Tree Protection

Not much diseases and insect pests is observed in Indian laurel. However, common mime butterfly (*Papilio clytia* Linn.) is recorded as defoliator. In severe attack of this pest complete eradication of leaves also noticed.

Management: For the management of leaf eating caterpillar collection and destruction of early instars of caterpillar should be done. At severe attack spraying of contact insecticides like Quinalphos 25 EC @ 2ml/lit. of water at 10-15 days interval should be done.

Orientation

Boundary/in field/on bunds/pond dyke/homestead garden



Assam lemon as intercrop in Baghnala

Suitable Intercrop

It can be inter-cultivated with other broad leaved species in order to provide shade coverage in early period. Mixed planting of bean, groundnut and other legumes can also be done in first two years. It is recommended for forest planting in mixed system/agroforestry system. Planting can be done in row mixture or cluster plantation. Management rotation is for 10-15 years.

Yield/Annual Return including Tree Productivity

Harvesting: Leaves, twigs, ripe berries and bark are harvested. The tree remains productive for 30 years and survives for about 50 years. After harvesting of the tree if irrigation and fertilizer are provided, the stumps will regenerate to new coppice shoot, which can be inter cropped and can be harvested again after 7 years. Alternatively, bark can be collected without felling the tree. In such case, bark is harvested from 10th year onwards. The bark is peeled off in vertical stripe with 6 cm interspaced between each stripe. The peeled off area is renewed with fresh bark in 1-2 years. Then, the bark on the other areas can be peeled off without cutting the tree. This non-destructive method is recommended for bark harvesting.

If total bark is removed after 7.5 years the productivity will be:

Fresh weight of the wood (without bark)	= 92 kg/tree
Fresh weight of the bark	= 20 kg/tree
Dry weight of the bark (sun drying)	= 2.8 kg/tree
Number of tree after mortality	= 1000/ha
Dry weight of the bark	= 2800 kg/ha
Fresh leaf as fodder	= 150 kg/tree

Economics

Fresh bark @ Rs. 50/kg x 20 kg/tree x 1000 tree/ha = Rs. 10,00,000/ha/7.5 years

≈ Rs. 1,30,000/ha/year

Fresh wood (without bark) @ Rs. 3/kg x 100 kg/tree x 1000 tree/ha = Rs. 3,00,000/ha/7.5 year ≈

Rs. 40,000/ha/year

Fresh leaf as fodder @ Re. 1/kg x 150 kg.tree x 1000 tree/ha = Rs. 1,50,000/ha/year

≈ Rs. 20,000/ha/year

Income from intercrops (average) @ Rs. 25,000/ha/year

Total income = Rs. (1,30,000 + 40,000 + 20,000 + 25,000)/ha/year = Rs. 2,15,000/ha/year

Cost of cultivation = Rs. 30,000/ha/year

Net income = Rs. (2,15,000 - 30,000)/ha/year = Rs. 1,85,000/ha/year

B:C ratio = 6.17

Use

Different parts of Baghnala are used for numerous purposes. The seed contains aromatic oil which is used in soap and candle industry. Bark has extensive commercial value and is principally used as a binding agent in incense stick industry. Root fibre is used for making ropes and paper pulp, the wood is utilized for making agricultural tools and implements. Young leaves are widely used as fodder. For treatment of various human ailments and diseases the plant is extensively used traditionally. Bark is considered as demulcents and mild astringents in diarrhea and dysentery. It is also aphrodisiac, anodyne and local antidote to bites of several venomous creatures. Ground bark is used either dry or triturated in water or milk as emollient and applied to bruises and as styptic dressing for wounds. The leaf and the mucilage in the gum of bark have been widely used for poultice. Oil from the berries is used in rheumatism. Seed powder is also utilized for treatment of skin boils. Recently, the bark of the plant has been commercially tried to be used as the binding agent in tablet formulations in medicinal industry and as plasters for fractured limbs.

Environmental Benefit

Baghnala is considered as a disappearing useful multipurpose tree and is subject to a conservation programme. It has high invasion potential and replaces regenerating native plant species in disturbed environments. Its utilization as fodder somewhat alleviates its pest status. The invasive properties of the plant can also be used for restoration of soils in degraded land.

Way Forward

Baghnala based Agri-silviculture or Horti-silviculture system has tremendous scope especially in the foot hill region, flood free areas and in areas where soil degradation is a problem.

Bhaluka banh (*Bambusa balcooa* Roxb.)

Agroforestry Model: Agri-Silviculture, Horti-Silviculture

Common Name: Balcooa Bamboo

Assamese name: Bhaluka banh

Family: Poaceae

Introduction

Bambusa balcooa Roxb. is a sympodial (clump forming) bamboo species having low gestation period, fast growth, diversified uses and easier marketability; all ensuring it's potential as an excellent agroforestry crop and advantage over many other perennial cash crops. This species is distinguished by the characters of - (i) young shoot blackish green with acute tip; (ii) culm coarse, stout, dull grayish-green with pointed re-curved branch-let towards the base; (iii) culm sheath without auricles. This species is widely grown in homestead, farmlands and other available places on farm holding.

Habit and Habitat

Bhaluka is an evergreen or deciduous gregarious bamboo, 12-20 m in height, 8-15 cm in diameter. Bamboo grows well at temp 8⁰ to 36⁰ C, annual rainfall 1200-4000 mm, high humidity. It prefers moist valleys, sheltered depressions and along stream and hill slopes up to 600m. It succeeds in any type of soil but prefers heavy textured soils with good drainage and pH of about 5.5 although can tolerate pH range from 4.5 to 7.5.

Distribution

Bhaluka is a common homestead bamboo in North East India (especially Assam, Nagaland, Meghalaya & Tripura), West Bengal, Bihar, Jharkhand, Uttaranchal and eastern UP.

Phenology

The culm is dark green colour, thick-walled, diameter of the cavity is one third of culm; nodes thickened with a whitish ring above, hairy below; internodes 20-40 cm long; branches from lower nodes are leafless and hard, mostly spreading, sometimes thorn like; young shoots blackish green, green with yellow, brown or orange tinged culm sheath, clothed sparsely with dark brown hairs. Leaves are 15-30 cm long, 2.5-5.0 cm broad, oblong lanceolate, glabrous above, pale and puberulous beneath, margins rough, apex pointed, somewhat heart shaped or rounded at base with a short stalk. Inflorescence is a large panicle, bearing spikate branching with bracteates heads, 0.6-1.2 cm long, 4-6 mm broad with 0-2 empty glumes.

Propagation Technology

Natural propagation: Seed

Artificial Propagation: Rhizome, culm/branch cutting and tissue culture

Nursery technology

Rhizome: Rhizomes of one year old culm should be selected as planting material. Rhizomes with one meter culm length having at least 2 – 3 internodes should be taken for the purpose. Rhizomes are to be planted during Mar-Aug in pit size of 45 cm x 45 cm x 45 cm at 45° angles inclined towards North; the base should be tempered tightly.

Culm cutting/branch cutting: Modified vegetative methods like culm cutting/branch cutting are more effective than conventional methods for large-scale multiplication of bamboo. In culm-cutting, horizontal planting of two-nodal cuttings is more effective than three-nodal culm cuttings of Bhaluka during summer in sand bed. Culms with shoots are taken out of each bed after emergence of well established shoots and roots; these plantlets should be transferred to plastic pots filled with sand in greenhouse for one month.

Micro propagation: Nodal segments are surface sterilized with 0.1% mercuric chloride for 10 min, and cultured on Murashige and Skoog (MS) medium supplemented with 4.4 µM 6-benzylaminopurine (BAP), 2.32 µM kinetin (Kn), and gelled with 0.2% w/v gelrite. Eighty-five percent of explants could be established *in vitro* with 90% of this achieving bud break. *In vitro*-formed shoots is being successfully multiplied in MS liquid medium supplemented with 6.6 µM BAP, 2.32 µM Kn, 2.5% v/v coconut water, and 100 mg l⁻¹ *myo*-inositol. Subculturing shoots every 3 weeks yields a consistent proliferation rate of 4.11-fold without decline in vigor. Shoot clusters, containing 5 to 8 shoots, are being rooted with 87.5% success in 1/2 MS supplemented with 5.71 µM indole-3-acetic acid (IAA), 4.9 µM indole-3-butyric acid (IBA), and 5.37 µM naphthaleneacetic acid (NAA) within 3 week. Plants regenerated in this manner should be acclimatized in the greenhouse and under a shade net with 88% success.

Cultural Operation

Land preparation: The area is to be demarcated with fence and cut down the bushes following ploughing atleast 15 days prior to planting.

Spacing: Bhaluka should be planted at the spacing of 5m x 5m for edible shoot production and 7m x 7m for culm production. A wider spacing of 12m x 10m may be suitable for growing intercrops at least for 4-5 years.

Pit size: 45 cm x 45 cm x 45 cm pits are to be dug, half filled and kept exposed to sun for 1 month to sterilize top soil.

Fertilizer application: Just prior to planting dry FYM @ 5 kg/plant, 50g Urea, 50g Super Phosphate and 50g Muriate of Potash should be applied in the pit.

Planting: With the onset of pre monsoon shower, the pit is to be filled with top soil and one year old seedling should be planted keeping in upright position. Care should be taken so that the roots

do not curl during planting in pits. Level the pit with enriched soil and compacted to eliminate all air pockets. Mulch the soil around the plants will help control weeds and keep the soil moist.



Bhaluka block plantation

Tending Operation

Soil loosening: Soil should be loosened to a depth of 10 – 15 centimeters, and 30 –45 centimeters away from the bamboo clump at least twice a year. It improves the growth of shoots and the root system.

Weeding: Regular weeding is necessary to prevent weeds and other vegetation from competing with the young bamboo for sustenance. Weeding should be done at least for the first two years after the rains and end of the wet season. Once the clump gets established there is considerable leaf shedding and this acts as a barrier to the emergence of weeds.

Mulching: Mulching reduces loss of moisture due to evaporation from the planting pits and checks weed growth. In grown up bamboo field, fallen bamboo leaves serve as good on-site mulching material. Bamboos have a requirement of silica for growth that can also be contributed by bamboo leaf mulch.

Mounding: Rhizomes grow laterally under the soil surface and when ready to throw up shoots, begin to grow upwardly inclined angle as well. In this period of growth, exposure to sunlight

retards and may even stop the growth of rhizomes. Mounding or heaping fresh, loose soil around and over the base of the plant is important as preventive measure against lodging.



Pineapple and banana as intercrop in Bhaluka

Pruning and cleaning: Regular pruning and cleaning should be carried from the 4th year of clump establishment. All dry, dead and drying culms are to be removed from the clump so as to provide sufficient space in the clump for new shoot. Branch pruning also provide sufficient space for the emerging culms to grow upwards quickly without any hindrance. These operations are to be carried out every year during January-February.

Management of congestions: From third year onwards thinning of the clump is essential to avoid congestion and to ensure proper growth and easy extraction of culms. Weak and deformed culms should not be retained in the culm. An appropriate clump structure should be maintained through thinning as well as through extraction or retention of shoots during Jan-Feb. Congestions in bamboo culms is a common problem caused by mismanagement especially during harvesting. Unrestricted cutting along the periphery of clumps, besides browsing of young shoots at the edges by cattle, continued removal of young tender shoots for edible purposes digging up rhizomes for making sticks, etc. prevent living rhizomes from spreading outwards. They, consequently, develop within the clump and the new culm so produced creates congestion. In extreme cases; clumps appear as tangled mass of twisted and crooked culm, in-penetrable and unworkable. Therefore, proper management activities are required to prevent or check this problem.

Tree Protection

Insect-pest: If managed properly with routine pruning, thinning and cleaning bamboo usually escapes pest infestations.

Disease: Bamboo blight caused due to *Sarocladium oryzae*.

Management: Fungal disease can be controlled with the application of Indofil M-45 at 75 WP or other suitable fungicides as soil drench. Blight can be managed by pruning and removing the infected parts after proper sanitation of pruning tools. Removal of blight infected culms, burring/burning debris in situ, adding new soil around clumps before the onset of monsoon is important to manage pests and diseases.

Animal: Clumps managed for edible shoots need protection from porcupines, wild pigs and household animals.

Management: This can cheaply be provided by encircling the clump with fishing net as barrier.

Orientation

Homestead/boundary/field/bunds

Suitable intercrop

Intercrops such as pineapple, banana, ginger and turmeric can be grown up to 4th year; however, due to profuse canopy of bamboo inter crops cannot be grown thereafter.

Harvesting

Edible shoot: For edible shoots tender sprouts are to be harvested within 3 weeks of emergence when they are about 30 to 40 cm in length. Ensure that not more than 60% of the sprouts are removed in one season. Soon after extraction the tender sprouts are to be taken for processing as drying of the sprout is detrimental for further processing.

Pole: Harvesting of bamboo culms every year will induces the emergence of new shoots and ensures regular and healthy culm production. Harvesting of bamboo for commercial purpose can begin from the third year of establishing a plantation. However the clump will mature and yield culms of full physical dimensions only after the fourth year. The best time of the year to harvest culm is in the post monsoon season extending through the winter.

Following points are to be noted at the time of harvesting:

- a) For non structural applications and those that do not require their peak physical and mechanical properties, 2-3 year old culms from a mature clump may be harvested;
- b) For most purposes however culms should be harvested when they are 4 years old;
- c) Culms that are more than 5 years old begin to turn brittle and weak and then die. As norm culms over 5 years should not be retained in a commercial plantation;
- d) In a clump containing 12 culms or more, at least 6 mature culms, over one year old should be retained;

- e) Culm should not be cut below the 2nd node; in any case not higher than 30 cm above ground level;
- f) No felling should be done during growing season.

Post harvest handling

Physical treatments like soaking in muddy pond for 1-8 weeks and slow drying under shade reduces insect attack. Chemical treatments with copper, arsenic, boron and fluoride compounds are also effective measures for enhancing durability by 5-6 times at the increased costs by about 25%. Some other methods for enhancing durability are:

- a) Treatment of green bamboo by diffusion and dry bamboo by sap displacement method;
- b) Treatment with commercial oil preservatives.

Yield/Annual Return including Tree Productivity

Harvestable bamboo yield = 600 to 700 nos./ha/year

Economics

System	Income (Rs/ha)			B:C ratio		
	Mean up to 4 th year	5 th year	7 th year	Mean up to 4 th year	5 th year	7 th year
<i>Bambusa balcooa</i> + Pineapple	2,06,571	86,532	76,700	6.75	3.26	9.59
<i>Bambusa balcooa</i> + Banana	93,057	30,640	82,500	3.57	1.25	10.31
<i>Bambusa balcooa</i> + Turmeric	1,78,592	37,132	96,700	3.68	0.73	12.09

Environmental Benefit

Nutrient build up: Built up of OM and plant nutrients in Bhaluka plantation take place enormously.

Carbon sequestration: Bamboo being C₄ plant contributes a lot for carbon sequestration and thereby cleanses the environment. Above ground C stock of Balcooa bamboo has been estimated as 84.06 Mg/ha in 10 years plantation.

Other benefit: In its natural area Balcooa bamboo is also often planted as a wind-break around farms and fields. Besides, it is a suitable species to check soil erosion.

Use

By virtue of their strength, straightness and lightness combined with hardness, range in size, hollowness, long fibre as well as easy working qualities, Bhaluka is suitable for numerous purposes as mentioned below:

- a) It is extensively used for house construction, farm fencing, production of pulp and paper, making agricultural implements, mats, screen, wall plate, basket, *agarbatti* stick and food grain container; It is highly esteemed for scaffolding and ladders;
- b) Bhaluka is widely used for making temporary bridges over pools, streams and rivulets in interior areas;
- c) Young shoot is consumed as vegetables and pickles; its leaves are used as fodder.

Way Forward

Bhaluka based Agri-Silviculture/Horti-Silviculture system has tremendous scope throughout the state. It is suitable in areas where soil degradation is a problem.

Coconut (*Cocos nucifera* L.)

Agroforestry Model: Agri-Horticulture, Horti- Horticulture, Aqua- Horticulture

Common Name: Coconut

Assamese name: Narikal

Family: Palmaceae

Introduction

Cocos nucifera L. is a multipurpose nut species which grows up to 30 m height and 50 cm in diameter with a single un-branched trunk; the base is thicker.

Habit and Habitat

Coconut prefers areas with abundant sun-shine and regular rainfall with 1500-2000 mm per annum; the species makes colonizing shorelines of the tropics and sub-tropics. The coconut palm thrives on varied soil and found abundantly in sandy beaches. It is tolerant to salinity. Coconut also needs high humidity (at least 70-80%) for optimum growth, for which they are rarely seen in areas with low humidity. It requires warm environment for successful growth, and is intolerant to cool climate. However, seasonal variation is tolerated where mean summer temperatures are between 28⁰C and 37⁰C, and survives winter temperature above 4⁰C - 12⁰C.

Silvicultural Characters

Coconut palm is intolerant of shade, and develops best when fully exposed to the sun; young plants, however, do best under slight shade. The root system forms a very firm anchorage for which it withstands gales very well, sound trees being seldom snapped or uprooted by strong winds; young fruits, however, are sometimes blown down during storms.

Distribution

Traditional areas of coconut cultivation in India are the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Odisha, Bengal, Puducherry, Gujrat, Maharastra and island territories of Laksha Dweep and Andaman & Nicobar. Coconut is cultivated in all the district of Assam; however, it is grown more abundantly in the districts of Nagaon, Morigaon, Sonitpur, Darrang, Kamrup, Nalbari, and Barpeta.

Phenology

Leaves are pinnate 4-6 m long, and pinnae 60-90 cm long; old leaves break away cleanly leaving the trunk smooth. Coconut fruit is a drupe. The palm produces both the female and male flowers on the same inflorescence; thus, the palm is monoecious. Other sources use the term polygamomonoecious. The female flower is much larger than the male flower. Coconut palm is

believed to be largely cross-pollinated, although some dwarf varieties are self-pollinating. The primordial of the inflorescence is reported to develop in the leaf axils about 32 months before the opening of the inflorescence. The primordial of the branches of inflorescence develop in about 16 months and male and female flowers in about 11 and 12 months, respectively before the opening of the inflorescence.

Propagation Technology

Natural propagation: Seed

Artificial Propagation: Seed

Nursery technology

Seed sowing in nursery: Seeds are sown in raised bed of 30 cm in height, 1 m in width and convenient length. Large size nuts are planted horizontally with the widest of the three segments upwards that helps in the plumule emergence. One year old seedlings having stout collar and 5-6 leaves become ready for planting.

Mulching: Mulching with 50 micron black polythene film is beneficial for coconut nursery to manage weed with a benefit: cost ratio of 2.36.

Cultural Operation

Land preparation: The area of planting should be completely cleared of all vegetations including root stocks and bushes. Land should be thoroughly ploughed followed by leveled properly.

Spacing: The seedlings are planted with the spacing of 7.5 m x 7.5 m.

Pit size: Pit size of 1 m x 1 m x 1 m is ideal.

Pit filling: Pit should be filled up with mixture of top soil, 20 kg compost or dried cow dung and 100 g of 5% malathion up to 2/3rd of the pit.

Fertilizer application: Fertilizers are applied in to split doses and applied twice in a year i.e. during Apr-May and Sep-Oct. The manures and fertilizers can be applied in a circular trench of 30 cm width and 10 cm depth, dug 1-1.75 m away from the trunk base; the amount should be as follows:

Year	Urea (g/tree)	SSP (g/tree)	MOP (g/tree)	Borax (g/tree)
1 st year	300	500	350	25
2 nd year	600	1000	700	25
3 rd year	900	1500	1050	25
4 th year	1200	2000	1400	25
5 th year onwards	1500	2500	1750	25

Planting: Planting should be done in Mar-Apr; however, under lowland situation it should be done during Sep-Oct.



Fodder as intercrop in Coconut

Tending Operation

Weeding: Light ploughing or harrowing should be done twice a year in Feb-Mar and Sep-Oct.

Irrigation: Palms should be irrigated in 10 days interval during the dry months from Nov to Mar.

Cleaning: Clean the palm twice a year before and after monsoon.

Rotation: Rotation period of coconut is 60-80 years.

Tree Protection

Insect-pest:

White ants or termites: Apply malathion 5% dust @ 200 g per 7.5 m² in nursery and in main field malathion 5% dust @100 g per pit should be applied during planting.

Rhinoceros beetle: (a) Apply malathion 5% dust mixed with equal quantity of sand at the axil of leaves of the crown; (b) apply naphthalene ball (hang on the base of the upper leaves) @ 1 ball/leaf in 2 upper leaves.



Turmeric as intercrop in Coconut

Red palm weevil: (a) There should not be any trunk cavity in red palm weevil endemic area i.e. trunk cavity should be kept sealed; (b) spray chlorpyrifos 20 EC @ 2 m/lit.; (c) pour chlorpyrifos 20 EC @ 2 m/lit. in the trunk cavity and plug with mud.

Coconut mite: (a) Application of proper nutrients (fertilizers and micronutrients) is important to manage coconut mite; (b) spraying of acaricides (e.g. Propargite @ 2 ml/lit.) onto bunches of developing fruits at 15 days interval.

***Terathea* and *Betrachedra* spp:** Clean the palm twice a year before and after monsoon and spray dimethoate 30 EC @ 1 ml/lit.

Disease:

Crown chocking: Apply 25 g Borax in a trench of 15 cm width and 10cm depth at a distance of 1 to 1.75m away from the trunk. In acute cases repeat the application after one month of first application for three times.

Stem bleeding: Scrape out the infected portion completely and apply Bordeaux paste or coal tar. Chiseling out of the infected portions followed by wound dressing with tridemorph (1 ml/lit.) or carbendazim (1 g/lit.) and finally application of hot coal tar will manage the stem bleeding disease of coconut.

Spindle rot: Spray 1% Bordeaux mixture immediately after emergence of seedlings.

Ganoderma disease:

- a) Drainage should be improved.
- b) Recommended dose of fertilizer should be applied.
- c) When disease symptoms are observed, isolate the diseased plant by digging a trench 60 cm deep, 30 cm wide and 1 m away from the trunk and drench the trench with 0.2% Captan.
- d) Application of 5 kg Neem cake per palm in addition to organic matter.
- e) Apply 1.5 to 2 kg Sulphur powder around the palm.
- f) Palms showing initial disease symptoms should be treated with 0.3% Captan or 0.2% Carboxin three times at monthly interval with 10 litres of solution per palm.
- g) Strict phytosanitary measures should be taken by removing the diseased palm along with roots and burying them completely.
- h) Grow one row of banana plant as a disease resistant crop in between two rows of coconut.
- i) Soil drenching with 1 g copper sulphate + 1.5 g Auriofungin solution in 100 ml of water.

Bud rot: Clean the affected portion and apply 1% Bordeaux mixture.

Leaf blight: Remove the older affected leaves and spray 1% Bordeaux mixture.

Immature nut shedding:

- a) Apply recommended dose of fertilizer per year.
- b) Apply pesticides and fungicides against pests and diseases.
- c) Irrigate the palms during dry months to prevent formation of abscission flowers at weekly interval for a month after fruit set.

Orientation

Boundary/in field/on bunds/homestead/pond dyke

Suitable intercrop

Crops like fodder (maize, sorghum, Oat, hybrid napier, etc.), rice nursery, pineapple, turmeric, ginger, banana (chenichampa & kachkal), assam lemon and vegetables like pumpkin, french bean, okra, brinjal, cowpea, colocasia, etc. have been found as profitable inter crops. Companion crops like black pepper, betel vine and Dioscorea may be grown profitably.

Yield/Annual Return including Tree Productivity

- a) Annual yield of french bean, okra and cowpea are 6.20, 7.23 and 3.30 t/ha, respectively as intercrop in coconut and fetches net income of Rs. 2,29,210/- per ha/year;
- b) Green fodder yield of maize is 41.15 t/ha as intercrop in coconut and fetches net income of Rs. 99,040/- per ha/year;
- c) The yield of turmeric and pineapple are 25.06 t/ha and 25.60 t/ha, respectively as intercrop in coconut and fetches net income of Rs. 5,17,730/- per ha/year and Rs. 4,45,125/- per ha/year, respectively.

Economics

Economic analysis reveal that pineapple (B:C ratio 9.22), turmeric (B:C ratio 5.78) and fodder (B:C ratio 3.39) are the most promising intercrops in coconut based agroforestry system.

Use

Coconuts are known for their versatility of uses, ranging from food to cosmetics. Mature and ripe coconut fruits (seeds) are used as edible; however, processed products like coconut milk and coconut oil from flesh, charcoal from hard shell, and coir from the fibrous husk are widely used for different purposes. Coconut oil and milk are used for cooking and in manufacturing of soaps and cosmetics. Coconut water obtain from immature nut is used as refreshing drink. Hard shells, fibrous husk and long pinnate leaves are used as decorative items. Coconut also has cultural and religious significance in Hindu rituals.

Environmental Benefit

Coconut is an ideal choice for large scale afforestation programmes especially in home garden. Traditionally it is a popular crop for growing in pond dykes. It helps in recycling of nutrients and improving soil health. It is estimated that maximum build up of organic matter (16.48%), available nitrogen (9.23%), available P_2O_5 (17.07%) and available K_2O (11.25%) occurs in coconut orchard while vegetables are grown as intercrop for 5 years. The species has immense potentialities for cleaning environment by fixing carbon. Above ground C stock of 35 year old coconut orchard is 10.165 Mg/ha.

Way Forward

Coconut based Agri-Horticulture, Horti-Horticulture and Aqua-Horticulture system has tremendous scope in the foot hill region and flood free areas especially in home gardens.

Gomari (*Gmelina arborea* Roxb.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Gmelina
Trade name:	Gamhar
Assamese name:	Gomari
Family:	Verbanaceae

Introduction

Gmelina arborea Roxb. is moderately sized to large deciduous timber tree with straight trunk. It is categorized as A-II timber. The tree is wide spreading with numerous branches forming a large shady crown, attains a height of 30 m or more and a diameter of up to 4.5 m.

Habit and Habitat

Gomari is best developed in moist, fertile, well drained soils. It is grown in acid, calcareous, alluvial or lateritic soil; preferable pH ranges from 5-8. Gomari grows in locations having the temperature range from 20⁰ C to 28⁰ C and the annual rainfall between 750 mm to 4500 mm. It is suitable in the altitude up to 1500 m above msl; however, it grows most luxuriantly up to the altitude of 525m. It can tolerate drought period upto 6 month per annum.

Gomari is a fast growing tree, annual increments of 3.0 m in height and 4.5 cm in diameter with wood density of about 439 kg/m³ at 15% moisture content.

Silvicultural Character

Gomari is a light demander species. It is moderately frost hardy and drought tolerant. The species has good coppicing power and produces vigorous coppice shoots. Seedlings and saplings are readily browsed by domestic Animals.

Distribution

Gomari is distributed in Bangladesh, Cambodia, China, India, Japan, Laos, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam. In India the species occurs in Western Himalayas, Aravalli Hills, Central India, Western Peninsula and in high silt deposited areas of Indo-Gangetic valleys. In Assam, Lower Brahmaputra Valley Zone and Central Brahmaputra Valley Zone are the most suitable for the species.

Phenology

Leaves are opposite decussate, mostly rather soft and limp; petioles cylindrical, 5-15 cm long, puberulent or glabrous; leaf, blade is broadly ovate, 10-25 cm x 7-20 cm wide, apically long

acuminate or caudate, entire on mature plant but strongly toothed or lobed on young plants, usually cordate or truncate basally, with a short cuneate attenuation into the petiole, densely tomentose above when young, becoming glabrous above when mature, permanently densely fulvous-tomentellous with stellate hairs beneath, glanduliferous just above the petiole on the basal attenuation. Gomari flowers during Mar-Apr; flowers abundant, scented, reddish, brown or yellow, in terminal and axillary 1-3 flowered cymes on the panicle branches, which are about 40 cm long. Flower 2.5-5 cm in diameter; bracts 8 mm long, linear lanceolate; calyx broadly campanulate, about 5 mm long, densely fulvous-tomentose externally, the rim with 5 small triangular, acute teeth; corolla large showy, varying from yellow to orange or brilliant orange to reddish or brownish yellow dull yellow brown, tubular below, obliquely funnel-form at the throat, the tube densely pubescent externally, the limb 2-lipped, the upper lip often orange-pink, deeply divided into 2 oblong, obtuse, backwardly curled lobules, the lower lip often lemon yellow, up to twice as long as the upper and 3-lobed. Fruit ripens in May-Jun; it is a drupe, 1.8-2.5 cm long, ovoid, seated on the enlarged calyx, glossy and yellow when ripe; exocarp succulent and aromatic; endocarp bony and usually 2-celled. Seed 1-3, lenticular, exalbuminous.

Propagation Technology

Natural propagation: Seed, coppice

Artificial Propagation: Seed, Root sucker, branch cutting and tissue culture

Nursery technology

Seed treatment for enhancing germination: There are 3 methods – i). Immerge in normal water for overnight, ii). Dip in hot water for 30 minutes and iii). Dip in concentrated Sulphuric acid for 5 minutes.

Seed sowing in nursery: Seeds are sown in drills directly in the root trainer or raised bed of 0.6 m in height, 1 m in width and convenient length. The bed should be filled with sand up to height of 0.5 m. The seeds are closely placed the bed in a rows with a gap of 5cm. The beds are to be watered twice in a day with the help of cane. Fresh seeds germinate quickly; germination percentage is about 70-90 %. The optimal temperature for germination is about 30°C. The seedbed should be exposed to full sunlight as partly or full shade will reduce germination. After germination, the seedlings can be transplanted to containers or to transplant beds at the spacing of 25 cm x 25 cm after the first rain.

Stump preparation: 8-10 month old seedling is uprooted from nursery bed; stem and roots are pruned keeping 30 cm stem and 15 cm primary root.

Cultural Operation

Planting time: Ideal time of planting is Mar-Jun with onset of pre monsoon shower. But plantation can be done throughout the year if proper irrigation facility is available. Entire plants may be planted; however, planting of stump in the main field is the most popular method of planting in Assam.



Toria as intercrop in Gomari

Spacing: The seedlings are planted with the spacing of 3 m x 3 m, 4 m x 4 m or 5 m x 5 m with intercrops. Block plantations for bio energy and pulp wood the spacing of 2 m x 2 m is the most suitable. For boundary plantation, 1-2 rows at the spacing of 1 m x 1 m should be adopted.

Pit size: Pit size of 45 cm x 45 cm x 45 cm is ideal.

Fertilizer application: Farm yard manure like cow dung, garden compost, vermin compost or any manure made from green leaves can be used. A basal application of 5 kg of FYM and 70 g of NPK complex fertilizer plus 10 g of borax is suggested.

Tending Operation

Weeding: In the 1st and 2nd year, weeding is done during June to August. Second year onwards weeding is not required. Soil working during October to November enhances the growth of plant.

Irrigation: 1-2 irrigations are necessary in first and second year during prolonged drought period.

Pruning: Pruning is an important practice in the cultivation of Gomari in farm land; pruning decides the growth, clear bole and intercropping ability. Pruning of side branches is usually carried out in every six months. The pruned branches can be used as fire wood.

Thinning: Thinning of Gomari is an important practice to enhance the production of saw log in block plantation. It begins at 4-5 years of age for the woods that are used for pulp production. The alternative trees in the row are to be thinned to avoid competition between the trees and maximize the growth. Thinning is recommended every 10 years where the rotation is 30-60 years.

Rotation: Matured marketable wood is obtained from 15th year onwards. However, marketable small diameter timber, suitable for poles, can be obtained at the age of 7-10 years.



Gomari block plantation

Tree Protection

Insect-pest: One of the most serious insect of Gomari in Assam is *Calopepla leayana*. It creates havoc mainly during May- June and August- September by eating up the leaf lamillae completely. Another important insect causing heavy damage to Gomari is *Alcides ludificalar* which bores longitudinal galleries on the cambial layer of the plant. Some other minor insect pests are *Chrysodeixis chalcites*, *Ancheronlia lachesis*, *Attachus* sp., *Glenea indiana*, *Ozola minor*, are observed in nursery.

Management: Spraying 0.2–0.3% Chlorpyrifos or Quinalphos or any contact insecticide. Insect attack may be drastically reduced in mixed plantation of Gomari with *Shorea robusta* (Xal), *Ficus hispida*, *Dipterocarpus turbinatus* (Garjan), *Acacia mangium* (Manjum), *Hopea odorata*. In mix plantation in line, Gomari may be grown with *Toona ciliata* (Poma) or *Chukrasia tabularis* (Bogi-poma). In alternate lines, Gomari may be grown with *Phoebe goalparensis* (Bonsom) addition application of fungi viz. *Beauveria bassiana* and *Metarrhizium anisopliae*, which are having the ability to control insects especially *Calopepla leayana* may also be applied.

Disease: Leaf spot disease is the most important disease of Gomari at seedling stage which is caused by the fungus *Orynespora cassicola*. The disease occurrence starts during last part of July and becomes havoc during October-November. Leaf spot disease can be controlled by spraying Mancozeb @ 0.25 % or Carbendazium M-45 @ 0.1 %. Other diseases are Collar rot, Damping off, Root rot, Nodal blast and leaf burning.

Management: Chemically seed treatment with Captan @ 0.25 % may be adopted. Seed can be treated organically with *Trichoderma viridi*, *Trichoderma harzianum* and *Aspergillus terreus* @ 0.5 % treated seeds should be planted in pretreated soil either with chemical Mancozeb @ 0.25 % or Carbendazium M-45 @ 0.1 or organically with Homicil/Neemcake/enriched organic matter @ 500 g/m².

Orientation

Boundary/in field/on bunds/homestead

Suitable intercrop

Field crops can be grown as intercrop up to 3rd year of plantation. Thereafter some shade tolerant crops like Pineapple, Turmeric, Ginger, vegetables and fodder etc. can be cultivated as intercrop. Black pepper, Betle vine and Dioscorea may be grown as companion crops.

Yield/Annual Return including Tree Productivity

In 16 years, Gomari yields 0.8614 m³ of timber/tree.

Economics

The total yield per hectare is around 250 – 300 tones / ha. The wood of Gomari fetches Rs.8000/ton in local market. Therefore, the annual return per hectare of 16th year old tree is Rs. 1, 25,000/-.

Use

The tree has immense potential for its all purposes timber and medicinal value. It is a preferred species by farmers, forest departments and ayurvedic industries due to the multipurpose utility, rapid growth, and maximum economic returns. Gomari wood is used for pulp, poles, particle board, plywood, matches, carpentry, planking, paneling, joinery, turnary and packing. It is also used for construction of boards, carving furniture, boxes and musical instruments. The leaves and fruits of Gomari are used as a fodder, and also used for rearing silkworms.

Environmental Benefit

It is an ideal choice for large-scale afforestation programmes due to its high carbon fixation ability (above ground C stock of 471.59 Mg/ha in 16 years). Intervention of Agri-silviculture system helps in recycling of nutrients and improving soil health.

Way Forward

Gomari based Agri-silviculture or Horti-silviculture system has tremendous scope especially in the foot hill region, flood free areas and in areas where soil degradation is a problem.

Jackfruit *Artocarpus heterophyllus* Lam.

Agroforestry Model: Agri-Horticulture, Horti-Silviculture, Hori-Horticulture
 Common Name: Jackfruit, Jak, Jack tree
 Assamese name: Kothal
 Family: Moraceae

Introduction

Artocarpus heterophyllus Lam. is an evergreen fruit tree species that has a relatively short trunk with a dense tree top. The timber is of medium quality and categorized as B-I. It reaches heights of 8 - 25 m and trunk diameter of 30 - 80 cm.

Habit and Habitat

Jackfruit grows in a wide range of tropical to sub-tropical environments. The optimum mean annual rainfall is 1000 – 2000 mm; it favours environments with uniform distribution of rainfall pattern throughout the year although grows in seasonally dry climate (< 40 mm rainfall) for 2 – 4 months. Mean annual temperature requirement of Jackfruit varies from 24 -28°C. It is most commonly found in lowland forest or homestead up to 250 m above msl., decreasing in abundance from 250 to 1000 m and sparsely from 1000 to 1600 m. The yield and quality of fruits decreased with the reduction of humidity. Jackfruit can grow on a wide range of soil like laterite, alluvial, shallow lime stone or calcareous, sand and rock substrates, etc.; however, it grows best in well drained deep soils of moderate to high fertility. The species grows luxuriantly in moderately acid to neutral soil (pH 5.0-7.5) with sandy loam to clay loam in texture. The species does not tolerate water logging or restricted drainage and declines or die if roots become water logged for 2 -3 days.

Silvicultural Character

Jackfruit is a shade bearer but it grows well in open areas. Seedlings are best grown in 30-50% sunlight and need sun exposure increasing to 100% as the tree matures. The species is definitely frost- tender and gives good coppicing. The tree re-grows well even after heavy pruning. It tolerates moderate wind and survives even hurricane force winds, recovering from loss of leaves and small limbs. The leaves and sometimes barks are eaten by animals.

Distribution

It is believed that Jackfruit is a native to the rain forests of Malaysia and the Western Ghats of India. However, it has been cultivated since prehistoric times and has naturalized in many parts of tropics and subtropics, especially in South East Asian and South Asian countries like India, Myanmar, Bangladesh, Sri Lanka, Malaysia, Thailand, Vietnam, the Philippines, South China,

etc. It is also grown in parts of Africa, Australia, Brazil, Suriname, the Caribbean and Florida in USA. Jackfruit has been introduced to many specific Islands like Fiji, Guam, Hawaii, etc. In India Jackfruit is mostly grown in Coastal & Eastern States. In Assam it is commonly found in home gardens and fallow lands of almost all the districts.

Phenology

Leaves are dark green, alternate, spirally arranged, entire, simple, glossy, leathery, skiff and elliptic to oval in form. The petiole is 2.5-7.5 cm long, the leaf blade is 17.5-37.5 cm long and 2.5-17.5 cm wide. Leaves are often deeply lobed when juvenile and on young shoots. The stipules are eggs-shaped with the length of 1.5-8.0 cm. The inflorescences are formed on the trunk, branches or twigs, pedunculated, cylindrical to ellipsoidal or pear-shaped, up to about 10-12 cm long and 5-7 cm wide. The species is monoecious, having male and female inflorescences (or spikes) on the same tree. The flowers are very small, there are several thousand flowers in an inflorescence, which sit on a fleshy rachis. Male and female spikes are found on younger branches above female spikes. The male flowers are hairy and the perianth ends with two 1.0 or 1.5 cm membrane. The individual and prominent stamens are straight with yellow roundish anthers. After the pollen distributions, the stamens become ash-grey and fall off after a few days. The greenish female flowers, with hairy and tubular perianth, have a fleshy flower-like base. The female flowers contain an ovary with a broad, capitate or rarely bi-lobed scar.

Jackfruit has a compound or multiple fruit (syncarp) with a green to yellow brown exterior rind that is composed of hexagonal, bluntly conical carpel apices that cover a thick, rubbery, whitish to yellowish wall. Seeds are light brown to brown rounded, 2-3 cm in length by 1.15 cm in diameter and enclosed in a thin whitish membrane. Seeds (up to 500 numbers) are recalcitrant and can be stored up to a month in cool, humid condition.

Flower appears from Dec to Mar and fruits with seeds ripen in rainy season.

Propagation Technology

Natural propagation: Seeds

Artificial Propagation: Seeds, entire planting, cutting, inarching air layering, cleft grafting, veneer grafting and epicotyls grafting. However, entire planting and epicotyls grafting are the most popular methods.

Trees grown from seeds (or entire planting) are generally deep rooted with a strong taproot facilitating firm anchorage besides providing greater resistance to drought as well as high wind. Besides these trees grow taller and produce longer trunks; therefore, jackfruit trees grown from seeds are better for timber production and as the wind break. On the other hand, grafted plants are more suitable for betterment of fruits productivity and fruit quality. The graft plants come to bearing within 4¹/₂ – 5 years when compared to entire planting which takes normally 7- 8 years.



Toria as intercrop in Jackfruit

Nursery technology

Seed collection: Seeds should be collected from fruits of trees with outstanding growth and fruit qualities.

Seed processing: The thin, slimy coating around the seed (parianth lobe) should be removed and the seeds are thoroughly raised in water. Only the largest seeds should be selected. Seeds may be air-dried in the shade for 1 hour, but they should never be allowed to dry out. Only freshly extracted seeds should be planted as the seeds are recalcitrant, i.e. they don't retain viability when dried or stored for extended period.

Pre-treatment: No pre-treatment is required. However, soaking in water at room temperature or in diluted gibberallic acid solution (25-200 ppm) for 24 hours prior to sowing hastens germination. Hot water treatment may also be used successfully to stimulate germination.

Sowing: Seeds should be sown in raised seed bed in rows at a spacing of 15-20 cm x 15-20 cm at a depth of 2 cm. Seed bed should be shaded partially. Daily watering is often needed once seeds germinate. The seedlings can be transferred to polythene bags after 4-5 weeks of emergence. Nine to ten months old seedlings (stem diameter 9 mm or more) are ready for planting.



Jackfruit block plantation

Entire planting: In entire planting seedlings are planted in main field at proper distance and at proper stage without distortion of roots.

Epicotyl grafting: Pre-treated seeds should be sown during Jul in poly bags of 10 cm x 20 cm filled with 1 part of sand, 1 part loamy soil and 1 part organic matter. After 10-12 days of emergence, the seedlings should be used as rootstock. Scion from the terminal shoots of selected good variety of one season old having well developed buds should be selected. Grafting should be performed by decapitating the seedlings at a height of 6 cm from the base and the top of stem should be split vertically to about 3.5 cm length forming a V-shape, 2.5 cm above the base. At the base of individual scion a wedge of 4.0 cm should be prepared and inserted in the split epicotyl region of the stock and tied firmly by polythene strip. As soon as grafting is done, the polythene bag should be placed under partial shade and water regularly. It may take 2-3 weeks for complete union of the scion with the rootstock. At this stage cap can be removed. The grafts are first replanted in a bigger container of 25 cm x 20 cm size and transferred to an open nursery.

Cultural Operation

Land preparation: The area of planting should be completely cleared of all vegetations including removal of all root stocks, bushes and other weeds. Planting area should be ploughed, harrowed and leveled properly.

Planting time: Ideal time of planting is Mar to Jun with onset of pre monsoon shower. But plantation can be done throughout the year if proper irrigation facility is available. The grafted plants may be planted during Jun-Sep.

Pit size: Pit size of 60 cm x 60 cm x 60 cm is ideal for entire planting and 1 m x 1 m x 1 m for grafted plant.

Spacing: For fruit production spacing for normal seedlings should be 10-12 m x 10-12 m and for grafted seedlings it should be 8 m x 8 m. However, for timber production the spacing should be 2-3 m x 3 m.

Planting: Pits should be dug 4 weeks before planting and should be kept open for 2 weeks. Then the pits should be filled with fertile top soil mixing with 10 kg of compost; water should be poured liberally to help settle the soil in the pit. After removal of polythene bags around the root system planting of 1-2 year old grafted plant or seedling should be done. Seedling (grafted or from seeds) should be positioned upright at the centre of the pit. Soil of the pit should be pressed firmly around the bases. Proper staking is required at least for 1 year to avoid lodging or subsequent breakage at graft joint in case of grafted plant. Watering immediately after transplanting is needed.

Manure and fertilizer application: Application of compost @ 10-30 kg/pl/yr should be continued till bearing. In the bearing stage manures and fertilizers should be applied per plant as compost 30 kg, N 200 g, P₂O₅ 320 g, K₂O 960 g and ash 5 kg.

Manure and fertilizer should be split in to two equal doses and applied in a 15 cm deep circular trench around 50-60 cm away from the trunk.

Tending Operation

Fencing: It is necessary to maintain fence of 1.5-2.0 m either around the area or around the individual tree for the initial period of 3-4 year to protect young trees from domestic animals.

Weeding: In the initial 3-4 year, weeding is done during Jun to Aug twice or thrice a year.

Mulching: Mulching by thatch or black polythene is needed to protect from weeds and keep the soil moistened around the base.

Irrigation: Jackfruit does not normally require irrigation. However, during initial 3 years 2-3 irrigations may be required during prolonged drought period.

Training: Jackfruit trees are trained to a single stem, early side branches should remove so that a uniform smooth trunk develops for a height of 1.5-2.0 m (up to 4m for timber purpose plantation) and then side branches should be permitted to arise. The flower buds appear on trunk which should be kept free of vegetative growth.

Pruning: is not commonly practiced in Jackfruit. Non-pruned seedling trees generally develop a strong central leader, which is desirable for its timber value. However, grafted trees exhibit dwarfing tendency and branch very early in their growth. These branches need to be pruned continuously to achieve a reasonably productive trunk. Thereafter, branches may be allowed to grow at desired intervals. The inner branches of the canopy may be removed to allow more light

and air within the canopy. Regular pruning of weak, dead and diseased branches and removing all parasitic plants at the end of the rainy season may prevent insect infestation and disease infection. Tree height and canopy size may also be controlled, if desired, through pruning.

In Asia, jackfruits ripen principally from March to June, April to September, or June to August, depending on the climate, with some off-season crops from September to December, or a few fruits at other times of the year. Fruits mature 3 to 8 months from flowering. After harvesting, the fruiting twigs may be cut back to the trunk or branches to induce flowering in the next season. The fruits may be covered with paper sacks during initiation of fruit development stage to protect them from pests and diseases. The bags encourage ants to swarm over the fruit and guard it from its enemies.

Rotation: Matured marketable wood is obtained from 40th year onwards. Usually jackfruit tree, grown from seed, has a lifespan of 60 to 80 years.

Tree Protection

Insect-pest:

Bud Weevil (*Ochyromera artocarp*): The small whitish grubs of bud weevil bore into tender flower buds as well as fruits and induce premature drop. The adult weevils are greenish brown in colour and are found to eat the leaves.

Management: Remove the infested shoots, flower buds and fruits to check infestation.

Shoot and fruit borer (*Diaphania caesalis*): Among insect pests, the shoot and fruit borer, *Diaphania caesalis*, is a major pest of jackfruit. The insects lay eggs on tender shoots and flower buds and after hatching larvae bore into shoots, flower buds and fruit.

Management: (a) To protect them from egg laying, fruit may be covered with polythene bags and the affected parts removed and destroyed, (b) infestation may be checked naturally if the trees are regularly pruned of dead and diseased twigs and small shoots within the canopy, to allow sufficient light and air to pass through. Pruning may be done soon after harvest or at the end of rainy season, (c) spraying of chlorpyrifos 20 EC @ 2 ml/lit of water during flowering.

Bark Borer (*Indarbela tetraonis* and *Batocera* spp.): Bark borer bore holes in the bark.

Management: (a) Remove the dead branches where it lays its eggs, (b) burn affected twigs and dead branches, (c) clean the bark portion, insert a cotton ball soaked in kerosene into the hole and seal the hole with mud.

Disease:

Blossom rot, fruit rot or stem rot (*Rhizopus artocarp*): It was a serious disease, which causes 15 to 32% crop loss. The inflorescence, tips of the flowering shoots or the stalk of the tender fruits are infected and blackened by fungus. Flowers and fruits rot and drop prematurely.

Management: (a) Collect and destroy the fallen leaves and fruits under the tree, (b) spray 1 % Bordeaux mixture or Copper-oxy-chloride 2.5 g/lit. Three sprays must be given at 15 days interval.

Leaf Spot (*Phyllosticta artocarpina*): Light brown with double margin spots are prominent on leaves. Such leaves defoliate and give barren look to the trees.

Management: Spray 1 % Bordeaux mixture

Orientation

Boundary plantation/block plantation/waste land/homestead

Suitable intercrop

Field crops like sesamum in kharif and niger/toria in rabi season, vegetables, spices, pineapple and fodder crops can be grown as intercrop up to 8th year of plantation at 8 m x 8 m spacing. Fodder crop like hybrid napier can be grown thereafter. In homestead jackfruit can be grown along with other fruit crops like mango, coconut, arecanut, pineapple, etc.

Yield/Annual Return including Tree Productivity

Jackfruit yield commences from 5th year in grafts and 8th year in seedling trees. It produces 150 large fruits/tree/year; on an average 50-80 ton fruits/ ha can be harvested. In fourteen year jackfruit plantation timber production is 32.03 m³/ha.

Economics

In 14 year plantation the B:C ratio for sole tree is 8.18 in contrast to 4.51 in intercrop plot.

Use

The pulp of the immature fruits is used as vegetables or pickles. Young matured fruit is utilized as fruit or canned in brine. The ripe fruit is often eaten fresh or is processed into numerous delicacies including jam, jelly, paste, papad, chutney, custard, chips, etc. also used as a flavouring agent in ice-cream and beverages. It also makes an excellent dried fruit or preserved candy. The ripe bulbs, fermented and then distilled, produce potent liquor. The seeds are excellent addition to curries or can be eaten freshly cooked or dried with salt as a snack or milled to a flour-like consistency to add in the bread dough. These are also preserved in syrup or canned in brine. Young male flower spikes is consumed as vegetables or pickled. In many locations leaves are used as vegetables. The leaves are utilized as food wrappers in cooking or woven together to make plates.

Jackfruit leaves are useful fodder for goat and other domestic animals.

The latex is used as chewing gum in many countries. It is used as glue for mending chinaware and potteries and as caulking for boats and buckets. The resins of the latex are used in varnishes.

The inner bark can be made into cordage or cloth. A dye of characteristic colour is produced from the tannin of the bark which is utilized widely to colour the silk and robes of Buddhist monks.

The fallen leaves and pruned twigs and branches are used as household fuel. Jackfruit trees yield valuable timber for making high quality furniture, for house construction, masts, oars and musical instruments.

Roots, leaves, barks and other parts are used for medicinal purposes. An extract of roots is used in treating skin diseases diarrhoea and asthma, ringworm infestation and heals cracking of feet. An infusion of mature leaves and barks is used to treat diabetes and gall stones. Heated leaves are used to treat wounds, abscesses and ear problems and relieve pain. Extract of seed/bark is used for digestion. An extract from bark or rags or roots is used to release placenta after calving in cows. Crushed inflorescence is utilized to reduce bleeding in open wounds. Ripe fruits are used as a laxative.

The wood has a sedative property; its pith is used to produce abortion.

Environmental Benefit

Dense jackfruit canopy decreases the negative impact of rain, especially erosion, by providing perennial cover like a shade tree to the soil. Fertility status of soil is enhanced if fallen leaves are allowed to be rotten or incorporated into the soil. An increase of organic matter, available N, available P₂O₅ and available K₂O by 41.49%, 23.68% and 9.56%, respectively over initial status of soil in the intercropped plots in 14 years jackfruit plantation has been observed. Mulching of leaves reduces weed growth. The action of roots, especially taproots, grown into the soil benefits soil structure by reducing compaction; thereby facilitates soil conservation. Jackfruit trees grown from seeds reduce the effects of wind planted around a homestead.

Because of these factors jackfruit is an ideal choice for large scale afforestation programmes especially in home garden and wasteland. Intervention of Agri-Horticulture, Horti-Silviculture, and Horti-Horticulture systems helps in improvements of soil health by recycling of nutrients as mentioned above and reducing soil erosion. Moreover, the species has immense potentialities of cleaning environment by C fixation. It is found that 14 years old jackfruit plantation results in above ground C stock of 44.06 Mg/ha in intercrop plots.

Way Forward

Jackfruit based agroforestry system has tremendous scope especially in the foot hill region and flood free locations of the state.

Jati banh (*Bambusa tulda* Roxb.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Tulda Bamboo
Trade Name:	Jati Bamboo
Assamese Name:	Jati banh
Family:	Poaceae

Introduction

Bambusa tulda Roxb. is basically a household plant species grown in moist alluvial flat land under homestead, farmlands and other available places on farm holding. It is grown in homestead as every part finds one use or another in daily life of a farmer. Like any other bamboo, Jati is also having advantage over other perennial cash crop as it has low gestation period, fast growth, diversified uses and easier marketability; all ensuring its potential as an excellent agroforestry crop.

Habit and Habitat

Jati is an evergreen or deciduous, tufted, gregarious bamboo; 8-23 m in height, 5-10 cm in diameter. It grows well at temperature ranging from 9⁰ C to 32⁰ C, annual rainfall 1200-2500 mm, but tolerates 700 - 4,500 mm. It prefers moist, lowland, alluvial flat land in tropics or semi-tropics; it is found at elevations up to 1,500 m above msl. It grows best in fertile, medium to heavy soils and prefers a pH in the range 5 - 6, tolerating 4.5 - 6.5.

Distribution

Jati is native to the Indian subcontinent, Indo-China, Tibet, Myanmar, Thailand and South China; the species is naturalized in Iraq, Puerto Rico and parts of South America. In India it is found in the states of Assam, Bihar, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Bengal, Uttar Pradesh and Karnataka.

Under natural condition the species is grown extensively in semi-evergreen areas of Central Assam at Low Hills.

Phenology

Culm-internodes are hollow, terete, green to grey and 36–60 cm in length. The lateral branches are spreading and dendroid. The culm-sheaths are one time as long as wide, 15–23 cm in length, hairy, with tawny hairs, pubescent, truncate or convex at the apex, ciliate on shoulders and auriculate. The culm-sheath blade is cordate, erect and triangular. The leaves are cauline. The leaf sheaths are smooth on the surface and glabrous. The leaf sheath oral hairs are pale and setose. The leaf sheath auricles are falcate and the ligule is an enciliate membrane. The collar

with an external ligule. Leaf blade base is connected to the sheath by a hairy 0.2cm long petiole. Leaf blades are oblong or linear, 17–37 mm in width and 15–25 cm in length. The leaf blade midrib is evident. The leaf blade has 12–20 secondary veins. The leaf blade surface is hairy abaxially and puberulous, apex is acuminate and margins are scabrous. Inflorescence: Synflorescence is clustered at the nodes, bractiferous, in untidy tufts, with spatheaceous subtending bracts, with axillary buds at the base of the spikelet, leafless between the clusters and prophyllate below the lateral spikelets. Fertile spikelets: The spikelets comprise of four to six fertile florets with diminished florets at the apex, they are linear, break up at maturity and subterete. They disarticulate below each fertile floret and are 25–75 mm in length and 5 mm in width. The rachilla is clavate, with definite internodes, eventually visible between the lemmas, hairy at the apex and pilose. Glumes: Many with two to four empty glumes. Florets: Apical sterile florets are underdeveloped and resemble fertile florets. Fertile lemma are without keel, ovate, and are 12–25 mm in length and 7–8 mm in width. The lemma margins are ciliate or eciliate, the apex is acuminate or acute and mucronate. The palea has seven to nine veinations with ciliate keels. The palea apex is pubescent. Flower: Membranous, veined, ciliate and with three lodicules. The anthers are purple with a smooth tip, six in number and 7.5–10 mm in length. There are three stigmas. The ovary is pubescent on the apex and umbonate. Fruit: The pericarp is adherent to the caryopsis, 7.5 cm in length, hairy at the apex and sulcate on the hilar side.

Young culms are green, which become greyish green when mature and brown when drying. Young shoots are yellowish green in color with a powdery top. Culms are covered with white blooms. A band of white hairs occurs above the nodes. Branching occurs from the base to top. Aerial roots reach up to few nodes above. Internode length is 30–60 cm, and diameter is 0.8–1.2 cm. Culm walls are very thick. Nodes are prominent.

Culm sheaths are triangular with a conical blade, and straw-colored. The sheath proper is asymmetrical and 15–32 cm in length and 25–34 cm wide. Blade length is 5–10 cm. Auricles are unequal where the large one is rounded and situated on the side of the blade. The upper surface of the sheath is covered with blackish-brown hairs. The lower surface of the sheath is not hairy. Sheaths fall off early.

Propagation Technology

Natural Propagation: Seed, Coppice

Artificial Propagation: Rhizome, Stem cutting, Tissue culture

Nursery technology

Seed: Seed remains viable for about 1 month only; when stored dry (in a desiccator over silica gel) viability can be extended to up to 1.5 years. Seed weight is about 70 g per 1000 seeds. Seed germination is 70% within 8 weeks after sowing. Excellent seedlings are obtained 18-20 weeks after sowing when the seedlings are fertilized with a mixture of 100 ppm urea and 50 ppm P₂O₅ in split applications 4, 6, and 8 weeks after germination.



Jati block plantation

Rhizome: Propagation by rhizome cuttings with direct planting in the field is very successful (survival more than 90%) and average height of shoots 2-5 months after planting is 1.35 m height. Rhizome parts can best be taken at the beginning of the rainy season.

One year old culm should be selected as planting material. Rhizomes with one meter culm length having at least 2 – 3 internodes should be taken for the purpose. Rhizome and root system is carefully separated from the mother clump. Cut end is covered with mixture of mud and cow-dung to prevent drying up.

Culm cutting/branch cutting: Modified vegetative methods like culm cutting/branch cutting are more effective than conventional methods for large-scale multiplication of bamboo. In culm-cutting, horizontal planting of two-nodal cuttings is more effective than three- nodal culm cuttings of Tulda bamboo during summer in sand bed. Use of NAA, IAA along with Kinetin in the month of Jul enhances quicker root growth. Culms with shoots are taken out of each bed after emergence of well established shoots and roots; these plantlets should be transferred to plastic pots filled with sand in greenhouse for one month.

Micro propagation: Nodal segments are surface sterilized with 0.1% mercuric chloride for 10 min, and cultured on Murashige and Skoog medium supplemented with 4.4 μ M 6-

benzylaminopurine (BAP), 2.32 μM kinetin, and gelled with 0.2% w/v gelrite. Eighty-five percent of explants could be established *in vitro* with 90% of this achieving bud break. *In vitro*-formed shoots is being successfully multiplied in MS liquid medium supplemented with 6.6 μM BAP, 2.32 μM kinetin, 2.5% v/v coconut water, and 100 mg l⁻¹ *myo*-inositol. Subculturing shoots every 3 weeks yields a consistent proliferation rate of 4.11-fold without decline in vigor. Shoot clusters, containing 5 to 8 shoots, are being rooted with 87.5% success in 1/2 MS supplemented with 5.71 μM indole-3-acetic acid, 4.9 μM indole-3-butyric acid, and 5.37 μM naphthaleneacetic acid within 3 week. Plants regenerated in this manner should be acclimatized in the greenhouse and under a shade net with 88% success.



Pineapple and turmeric as intercrop in Jati

Cultural Operation

Land preparation: The area is to be demarcated with fence and cut down the bushes following ploughing atleast 15 days prior to planting.

Spacing: Jati should be planted at the spacing of 5m x 5m for edible shoot production and 7m x 7m for culm production. A wider spacing of 10m x 10m may be suitable for growing intercrops at least for 4-5 years.

Pit size: 45 cm x 45 cm x 45 cm pits are to be dug, half filled and kept exposed to sun for 1 month in order to sterilize the top soil.

Fertilizer application: Just prior to planting dry FYM @ 5 kg/plant 50g Urea, 50g Super Phosphate and 50g Muriate of Potash should be applied in the pit.

Planting: With the onset of pre monsoon shower, the pit is to be filled with top soil and should be planted keeping in upright position. Care should be taken so that the roots do not curl during

planting in pits. Level the pit with enriched soil and compacted to eliminate all air pockets. Base should be sprinkled with water frequently. Mulching the soil around the plants is helpful to control weeds and keep the soil moist. It is advisable to protect them from grazing of domestic animals.

Tending Operation

Soil loosening: Soil should be loosened to a depth of 10 – 15 centimeters, and 30 –45 centimeters away from the bamboo clump at least twice a year improves the growth of shoots and the root system.

Weeding: Regular weeding is necessary to prevent weeds and other vegetation from competing with the young bamboo for sustenance. Weeding should be done at least for the first two years after the rains and end of the wet season. Once the clump gets established there is considerable leaf shedding and this acts as a barrier to the emergence of weeds.

Mulching: Mulching reduces loss of moisture due to evaporation from the planting pits and checks weed growth. In grown up bamboo field, fallen bamboo leaves serve as good on-site mulching material. Bamboos have a requirement of silica for growth that can also be contributed by bamboo leaf mulch.

Mounding: Rhizomes grow laterally under the soil surface and when ready to throw up shoots, begin to grow upwardly inclined angle as well. In this period of growth, exposure to sunlight retards and may even stop the growth of rhizomes. Mounding or heaping fresh, loose soil around and over the base of the plant during winter is important as preventive measure against lodging.

Pruning and cleaning: Regular pruning and cleaning should be carried from the 4th year of clump establishment. All dry, dead and drying culms are to be removed from the clump so as to provide sufficient space in the clump for new shoot. Branch pruning also provide sufficient space for the emerging culms to grow upwards quickly without any hindrance. These operations are to be carried out every year during January-February.

Management of congestions: Thinning the clump is essential from third year onwards to avoid congestion and to ensure proper growth and easy extraction of culms. Weak and deformed culms should not be retained in the culm. An appropriate clump structure should be maintained through thinning as well as through extraction or retention of shoots during Jan-Feb.

Congestions in bamboo culms is a common problem caused by mismanagement especially during harvesting. Unrestricted cutting along the periphery of clumps, besides browsing of young shoots at the edges by cattle, continued removal of young tender shoots for edible purposes digging up rhizomes for making sticks, etc. prevent living rhizomes from spreading outwards. They, consequently, develop within the clump and the new culm so produced creates congestion. In extreme cases; clumps appear as tangled mass of twisted and crooked culm, in-penetrable and unworkable. Therefore, proper management activities are required to prevent or check this problem.

Tree Protection

Disease: Jati bamboo has no serious diseases or pests. It is slightly to moderately susceptible to bamboo blight (*Sarocladium oryzae*) which attacks young bamboos during or soon after elongation growth, usually followed by secondary insect infestation which aggravates the damage.

Management: Drenching the soil of affected clumps with a fungicide (e.g. Mancozeb @ 0.25 %) before the onset of rain. Wilting and death of young shoots caused by *Oregma bambusae* can be controlled by the application of Carbendazim @ 0.01%.

Insect-pest: Shoot borers (e.g. *Dinoderus* spp., *Lyctus africanus*, *Stromatium barbatum*) can cause considerable losses in cut culms.

Management: Treating the culms with Malathion 10% D or 3% boric acid/borax mixture (1 : 2) may give effective protection.

Orientation

Homestead/Boundary/field/bunds

Suitable intercrop

Horticultural crops such as pineapple, banana, ginger and turmeric can be grown as intercrops up to 4th year; however, due to profuse canopy of bamboo inter crops cannot be grown thereafter.

Harvesting

Normally 3-4-year-old culms are harvested, retaining at least 3-6 evenly spaced culms per clump. A 4-year felling cycle is often adopted. Young shoots to be used as a vegetable should preferably be harvested while attaining a height of 25-30 cm. Following points are to be noted at the time of harvesting:

- a) For non structural applications and those that do not require their peak physical and mechanical properties, 2-3 year old culms from a mature clump may be harvested;
- b) For most purposes however culms should be harvested when they are 4 years old;
- c) Culms that are more than 5 years old begin to turn brittle and weak and then die. As normal culms over 5 years should not be retained in a commercial plantation;
- d) In a clump containing 12 culms or more, at least 6 mature culms, over one year old should be retained;
- e) Culm should not be cut below the 2nd node; in any case not higher than 30 cm above ground level;
- f) No felling should be done during growing season.

Post harvest handling

Traditionally, physical treatments like soaking of culms in running water for 10-20 days followed by slow drying for 7- 15 weeks under shade enhances tolerance against powder post

beetles. Chemical treatment with the solution of Sodium Carbonate, Calcium Hydroxide, Copper Sulphate, etc. enhances durability by resisting cracking and collapsing along the entire length of internodes of the culms. Some other methods for increasing durability especially in industrial sector followed are:

- a. Treatment of green bamboo by diffusion and dry bamboo by sap displacement method;
- b. Treatment with commercial oil preservatives.

Yield/ Annual Return including Tree Productivity

After 7th years of plantation, the harvestable yield of Jati is 1110 nos./ha; however, the production of harvestable bamboo intercropped with pineapple, banana and Turmeric becomes 1140, 1280 and 1260/ha, respectively. The annual yield of dry culms is about 3 ton/ha in Assam.

Economics

System	Income (Rs/ha)			B:C ratio		
	Mean up to 4 th year	5 th year	7 th year	Mean up to 4 th year	5 th year	7 th year
<i>Bambusa tulda</i> + Pineapple	1, 95,390	1,20,510	68,400	7.24	5.05	8.55
<i>Bambusa tulda</i> + Banana	50,400	50,247	76,800	2.09	2.27	9.60
<i>Bambusa tulda</i> + Turmeric	1, 59,438	79,245	75,600	3.27	1.72	9.45

Use

In North East India, Tulda bamboo is used extensively for covering the houses and scaffolding. The young shoots are used for making pickles of excellent quality. It is used extensively for manufacture of wrapping, writing and printed paper. It is also used for making toys, mats screens, wall plates, wall hanger hats, baskets, food grain container, flute, etc. It is used as reinforcement in cement concrete. The fermented shoots can be used for making sterol drugs.

Tender shoots are rich in antioxidants which confer health benefits such as prevention of cancer and degenerative diseases, slowing down the aging process and promotion of cardiovascular health. The main antioxidants in bamboo leaves and shoots are phenols, vitamin C and vitamin E and mineral elements such as selenium, copper, zinc, iron and manganese.

Environmental Benefit

Nutrient build up: Built up of OM and plant nutrients in Tulda bamboo plantation take place enormously.

Carbon sequestration: Bamboo being C₄ plant contributes a lot for carbon sequestration and thereby purified the air enormously from CO₂ pollution.

Other benefit: In its natural area it is also often planted as a wind-break around farms and fields. Besides, it is a suitable species to check soil erosion.

Way Forward

Jati bamboo based Agri-silviculture and Horti-Silviculture system has tremendous scope throughout the state. It is suitable in areas where soil degradation is a problem. It is also suitable for plantation in waste land and industrial areas.

Mahaneem (*Azadirachta indica* A. Juss.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Neem
Trade name:	Neem
Assamese name:	Mahaneem
Family:	Meliaceae

Introduction

Azadirachta indica A. Juss. is a multipurpose evergreen tree, but in dry areas it becomes deciduous.

Habit and Habitat

Mahaneem grows well on widely varied soil; it grows well in moist, dry, stoney, clayey or shallow soils. However, water inundated areas are not conducive for its growth. It can tolerate a wide range of soil pH from 5-10. Mahaneem grows luxuriantly on deep well drained soil with deep sub soil water level. It survives best in altitudes between 50 to 100 m above msl, rainfall ranges between 480 to 1000 mm, and a temperature ranging from 0°C to over 40°C.

Silvicultural Character

Mahaneem is light demander, but has capacity for pushing its way through scrub in young stage in seedling and sapling stage, species is very frost tender. It is sensitive to fire, drought hardy and cannot stand water stagnation. It coppices well and produces root suckers especially in dry localities. The species is not readily browsed by cattle and goats

Distribution

Mahaneem is native to arid and semi arid regions of India. It grows all over India from arid to moist tropics and sub tropics. In Assam, the rain shadow belt including Karbi Anglong, Hojai, Nagaon and parts of N.C.Hills is considered suitable for its commercial plantation. In Brahmaputra valley the hillocks are suitable for its plantation.

Phenology

Leaves alternate crowded near the end of branches, simply pinnate, 20-40 cm long, light green, with two pairs of glands at the base, otherwise glabrous; petiole 2-7 cm long, subglabrous; rachis channeled above; leaflets 8-19, very short petiolated, alternate proximally and more or less opposite distally, ovate to lanceolate, sometimes falcate 3.5-10x1.2-4.0 cm, glossy, serrate; apex acuminate; base unequal. Inflorescence an axillary, many flowered thyrsus, upto 30 cm long; bracts minute and caduceous; flower bisexual or male on the same tree, actinomorphic, small, pentamerous, white or pale yellow, slightly sweet scented; calyx lobes imbricate, broadly

ovate and thin, puberulous inside; petals free, imbricate, spatulate, spreading, ciliolate inside. Fruit 1 or 2 seeded drupe, ellipsoidal, 1-2 cm long, greenish, greenish yellow or purple when ripe; exocarp thin, mesocarp pulpy, endocarp cartilaginous; seed ovoid or spherical; apex pointed; testa thin, composed of a shell and a kernel (sometimes 2 or 3), each about half of the seed's weight.



Mahaneem tree

Propagation Technology

Natural propagation: Seed, coppice and root suckers

Artificial propagation: Seed, planting entire plant with ball of earth (ETP), root and shoot cutting.



Mahaneem at boundary

Nursery Technology

Pretreatment of seeds: Pre-treatment of seed in cold water for 24 hours increases germination percentage.

Seed sowing in nursery: Seeds have short viability of 2-3 weeks and so mature seeds should immediately be sown in seed bed in rows of 15- to 20 cm apart and at the distance of 2.5 to 5 cm within rows. The seedling can be raised in basket and also in polythene bag. About 2 months to 1 year old seedling can be transplanted in the main field when they attain 10-15 cm height. Preparation of stumps from 2 year old seedlings gives better result than those from 1 year old seedlings. Stumps should possess 2.5 cm of shoot and 20 cm of root.

Cultural Operation

Land preparation: The area of planting is completely cleared of all vegetation including removal of all root stocks and herbs/shrubs. Land should be prepared by ploughing and harrowing.

Spacing: 4 m x 5 m.

Pit size: Pit size of 45 cm x 45 cm x 45 cm.

Fertilizer application: Compost or FYM @ 5 kg/pit.

Planting: Pits are dug and left for 15-20 days exposing to sunlight. Pits are filled up in such a way that water does not accumulate in pit. Time of planting is March to June with onset of pre monsoon shower; however, plantation can be done throughout the year if proper irrigation facility is available.

Tending Operation

Soil working: Soil working and weeding are beneficial for growth and development.

Weeding: Usually 3 weeding along with soil working in the 1st year and 1 weeding in the 2nd year are required.

Pruning: Periodical pruning of the tree once in a year during Nov-Dec provides a good framework and faster growth of foliage as well as seed production of the tree.

Harvesting

Mahaneem starts flowering from 5th year onwards. A full grown tree produces about 350 kg leaves and 50 kg berries. About 7-8 years old tree starts producing fresh leaves which increases with age till 20th year.

Tree Protection

Insect-pest: One of the most common insect is Tea mosquito bug (*Helopeltis antonii*). Nymphs and adult suck the sap from plant tissues after sunset.

Management: Spray Chlorpyrifos 30 EC or Malathion 50 EC @ 2ml / lit of water in the evening hours for controlling the insect.

Orientation

Boundary/in field/on bunds/homestead

Suitable intercrop

All the field crops including oilseeds and pulses, vegetables, spices, pineapple and forage crop can be grown.

Use

Dried leaves are extensively used to protect grains, seeds, clothes, etc. from storage insects. It is used to treat skin diseases like eczema, psoriasis, leucoderma, etc. Mahaneem products are believed to be anthelmintic, antifungal, antidiabetic, antibacterial, antiviral, contraceptive and sedative. Neem oil is used for healthy hair, to improve liver function, detoxify the blood, and balance blood sugar level. Neem products are widely used for industrial purposes like preparation of medicated soap, hair lotion, face cream, tooth paste, disinfectant, pesticides, etc. The heart wood is resistant to termite and durable; therefore, the timber is used in house building, furniture, panels, agriculture implements, etc. It is a good fuel wood; leaves may be utilized as fodder. Seed cake is used for preparation of manures.

Environmental Benefit

Neem tree purifies air; as such it is suitable for plantation in urban and industrial areas. The extracts of leaf and seed kernel adversely affect certain fresh water wildlife including fish and tadpoles; therefore, Neem should not be planted in pond dyke.

Way Forward

Neem based Agri-Silviculture or Horti-Silviculture agroforestry system has tremendous scope especially in flood free areas where soil degradation and air pollution is a problem.

Manjum (*Acacia mangium* Willd.)

Agroforestry Model: Agri-Silviculture, Horti-Silviculture
 Common Name: Australian Teak
 Assamese name: Manjum
 Family: Fabaceae

Introduction

Acacia mangium Willd. is a very fast growing evergreen timber tree species with a dense spreading crown growing up to 30 m height and 0.5 m diameter. It is typically occurs in humid tropics, primary and secondary forests, re-growth of woodland, open grassland, poorly drained flood plains and behind mangroves.

Habit and Habitat

The growing area of Manjum is characterized by a short dry season and a mean annual rainfall between 150-3000 mm; it can tolerate moisture stress, temperature requirement ranges from 31-37°C during summer and a minimum of 12-25°C in winter. The growth seems to be slow down with decreasing rainfall and temperature. Manjum can tolerate low fertility soils with impeded drainage, but prefers fertile soils with good drainage. It grows in a wide range of pH from 4.0-7.5 and has been found to tolerate water logging. The tree grows up to 900 m above msl.

Distribution

Manjum is native to Australia but intensively cultivated throughout India, Indonesia, Malaysia, Papua New Guinea, Sri Lanka, Thailand, Nepal and Bangladesh. In India several thousand hectares has come under this tree in the states of Kerala, Karnataka, Tamil Nadu, UP, MP, Odisha and Maharashtra. It has been introduced in Assam only in the last decade of 20th century.

Phenology

The dark green, glabrous phyllodes (leaves) are 18-25 cm long and 8-10 cm wide. Phyllodes are straight along one side and curved on the other side with 4-5 main longitudinal veins. Australian teak produces inflorescences on loose spike which are up to 10 cm long with many tiny white or cream coloured flowers releasing a mild sweet fragrance. Flowering time is Sep-Dec and fruit matures 3-4 months after flowering. The pods are 8-10 cm long and 3-5 cm wide, linear and are irregularly coiled. Pods change colour from green to brown on ripening and turn stiff and dry. The seeds are of varying shapes, brown to black in colour, 3-5 cm in diameter.

Propagation Technology

Natural propagation: Seed, coppice.

Artificial Propagation: Seed, stem cutting, grafting, air layering and tissue culture.

Pre-treatment of seed: Pre sowing treatment gives rapid and higher germination (75-90%) which occurs within 1 month. It can be done by any one of the following methods:

- a) Seeds are immersed in boiling water for 30 seconds followed by soaking in cold water for 24 hours;
- b) Soaking of seeds in concentrated Sulphuric acid for 10-30 minutes by soaking in cool water for 24 hours;
- c) Scarifying the seeds manually.



Manjum block plantation

Nursery Technology

Seed sowing: Seeds may be sown in seed beds and pricked out 6-10 days after sowing. Sowing in germination trays and pricking out the seedlings 6-10 days after sowing should be done when the radicle emerges giving 85 % survival. Another option is direct sowing in the containers (polythene bag, open-ended hanging pot called 'root trainers' or other permanent pot), followed by pricking out to maintain 1 seedling per container. The sowing media may comprise of the mixtures of top soil, peat, old saw dust, rice husks, sand and vermiculite. Seedlings of 25-40 cm height are ready for plantation in the main field.

Stem cutting: Single noded stem cutting of 4-5 cm long, 0.5-1.5 cm diameter with 0.5-1 phyllode gives profuse rooting. The application of Indole-butyric acid or rooting powder results in 65-75 % rooting in cuttings.

Air layering: It also gives promising results.



Fodder as intercrop in Manjum

Cultural Operation

Land preparation: Plough the land and level it properly. Mark the areas for pit digging by alignment and staking.

Pit size: 45 cm x 45 cm x 45 cm.

Spacing: 3 m x 3 m is the most common spacing for Manjum. It can also be reduced to 2 m x 2 m, 2.5 m x 2.5 m for fast growth and straight bole height in the initial stage. It can also be raised along with agricultural crops at the spacing of 5 m x 4 m. For boundary plantation 1-2 rows at the spacing of 2 m x 2 m should be adopted.

Planting time: Best planting season for Manjum is monsoon; preferably after the first shower.

Fertilizer application: Apply 5 kg of FYM in pit. Fertilizer application of NPK@ 50:100:50 kg/ha in the form of Urea, SSP and MOP/plant should be applied every year from 2nd year up to 5th year.

Tending Operation

Weeding: In the first year, weeding is done during June to August. Second year onwards weeding is not required.

Soil working: Soil working during Oct - Nov enhances the growth of plant.

Irrigation: 1-2 irrigations are necessary in first and second year during prolonged drought period.

Pruning: Pruning is an important practice in the cultivation of Manjum in farm land; pruning decides the growth, clear bole and intercropping ability. Pruning of side branches is usually carried out in every six months. The pruned branches can be used as fire wood.

Thinning: Thinning of Australian teak is an important practice to enhance the production of saw log in block plantation. It begins at 4-5 years of age for the woods that are used for pulp productions. The alternative trees in the row are to be thinned to avoid competition between the trees, and to maximize the growth.

Rotation: Trees are harvested 6-7 years after planting for pulp wood; for sawn timber the rotation is 15-20 years.

Tree Protection

Insect-pest: Important insect pests are root feeders (*Stenocera aequisignata* and termite), branch and stem borers (*Synoxylon* sp.) and red coffee borer (*Zeuzera coffeae*). These can cause death, deformity or reduced biomass production of *Acacia mangium*.

Management: As the preventive measure of *Stenocera aequisignata* in nursery, *Isobenzan* @ 0.59 kg/ha should be applied in soil. For controlling *Zeuzera coffeae* in the plantation, insecticides can be injected into the holes where larva pushes out their frass. For control of *Synoxylon* sp., the broken branches in which insect breeding has taken place is removed and burnt.

Disease: The important diseases observed in nursery are damping off, powdery mildew, stem galls, die back, leaf spot, charcoal root rot and root knot. Important diseases in plantation are root rot, heart rot, pink disease, die-back and stem canker. Root rots are caused by many fungus species like *Ganoderma* sp., *Phellinus* sp. and *Rigidoporus lignosus*.

Management: The dead and diseased trees should be destroyed to avoid spread of root rot diseases. There is no specific control measures at present for heart rot, die-back and stem canker. The diseases in nursery can be controlled by conventional nursery management techniques and prophylactic fungicidal spray.

Orientation

Boundary plantation/block plantation/waste land/homestead

Suitable intercrop

Sesamum in kharif and niger in rabi season give a good return up to 4th year in tree spacing of

5 m x 4 m; however, the productivity of intercrop is decreased with increased tree canopy. After such situation selected fodder crop can be grown as intercrop. All field crops, vegetables, fruits, spices, fodders, flowers, etc. can be grown in field surrounded by boundary plantation of Australian teak.

Yield/ Annual Return including Tree Productivity

Timber volume is calculated on the basis of mean data as 1.1902 m³/tree in 16 years plantation.

Economics

Income of Manjum based Agroforestry system in 16 years, where Sesamum-niger grows up to 4th year followed by Hybrid Napier, is Rs. 19, 25,680/ha or Rs. 1,20, 355/ha/year.

Use

Manjum is used to make excellent particle board and is suitable for plywood, paper pulp, fence post, firewood and charcoal. It is important source of wattle timber; the wood is used for construction, making boat, furniture and veneer. It makes attractive cabinets, mouldings, floors, doors and window components. It also serves as wind break and fire break. Manjum is a suitable crop for production of honey.

Environmental Benefit

Manjum is very fast growing and possesses the beneficial property of trapping atmospheric nitrogen; thereby increases soil organic matter and nutrients. It is the most suitable tree species for soil improvement in degraded and marshy land. Clean environment is obtained through the fixation of 170.9 Mg/ha of CO₂ in the form of wood in 16 year plantation of Australian teak in Assam.

Way Forward

Owing to the properties of rapid growth and tolerance of very poor soils, large scale cultivation of Manjum in lands unsuitable for conventional agriculture in Assam can be taken up. It may be helpful to increase the availability of wood logs in the state manifold. It has ample potentiality for plantation in wasteland including *char-Chapori* areas of the Brahmaputra River and its tributaries.

Sajina (*Moringa oleifera* Lam.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Drumstick, Ben
Assamese Name:	Sajina
Family:	Moringaceae

Introduction

Moringa oleifera Lam. is a small, fast-growing, drought tolerant, deciduous tree, often 8-10 m tall, sometimes to 12-18 m and girth of 1.1- 1.5 m.

Habit and Habitat

Sajina tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic (pH 6.3 to 7.0), well drained sandy or loamy soil at 25 – 30°C under sunny situation and can tolerate mild frost, but does not stand waterlogged situation. It can survive at high temperature of 45°C under shade. Drumstick tree losses its leaves during winter and then starts to give flower. Presence of a long tap root makes it thrive at areas with as low as 250 mm annual rainfall and resistant to long period of drought. In areas with rainfall over 3000 mm provision is to be made to encourage water-run-off and drainage. It is particularly suitable for growing at an altitude of 0 – 2000 m above msl.

Silvicultural Character

Sajina is strong light demander. It coppices and pollards very well. The species is hardy against frost, fire and mechanical injuries like cutting or brushing; however, it is susceptible to wind damage.

Distribution

Sajina is native of sub-Himalayan tracts of India but has spread and become naturalized in semi-arid to humid tropics and sub-tropics. Andhra Pradesh, Karnataka and Tamil Nadu grow it extensively in commercial scale and occupy more than 70 % of the national total area and production. Although it gives a very luxuriant growth in the eastern and north eastern plains its cultivation is unorganized and confined to homestead and boundary planting. In Assam, Sajina is luxuriantly grown in rain shadow areas of Hojai, Nagaon, Karbi Along, Golaghat and Kamrup district.

Phenology

Leaves are imparipinnate, rachis 12-25 cm long, pubescent, 5-10 pairs of pinna 3-6 mm long, each with 6-9 pairs of pale green, obovate leaflets 1-2 cm long, terminal leaflets slightly larger,

basal leaflet pairs sometime tripinnate. Sweet-scented flowers, cream white, arranged in panicles, with 5 unequal petals slightly larger than the sepals, petals narrowly spatulate, veined, white, bracts linear, calyx 5-lobed, linear-lanceolate, reflexed, puberulous outside, 5 stamens, fertile alternating with 5-7 staminodes, filaments villous at the base, ovary 1-celled, oblong, villous, ovules many, style slender. The long, pointed and triangular cross-section fruits are very distinctive, up to 1-2 cm broad, often 30-50 cm long, up to 120 cm long in some cultivated varieties, containing oily black seeds up to 1 cm in diameter in a typical 3-winged seed coat.



Sajina at boundary

Propagation Technology

Natural propagation: Seed, coppice

Artificial propagation: Seed, coppice, branch cutting, stem cutting, planting out entire (ETP), stump planting

Nursery technology

Seed sowing in nursery: Seeds being non-dormant are sown immediately after extraction from mature pods. Seeds remain viable for about three months and take 20 – 30 days for germination.

Use of poly bags is recommended because there is less damage to seedlings when they are transplanted. Seedlings are to be grown under shade or in a screen house. However, stem and branch cuttings are the most common practice in Assam.

Stem cuttings: The plant can be easily propagated through hard wood cuttings which are planted directly in the field as it is highly sensitive to transplanting shock. One third length of 45 cm-1.5 m long and 10 cm thick cuttings should be buried in the pits prepared at 4 m distances. Application of rooting hormone before planting gives better results. Vegetative propagation is best during onset of monsoon after harvesting the fruits. Cuttings planted in nursery bags with 3:1 garden loam and sand mixture can be planted in main field after 2-3 months without disturbing the root system.

Cultural Operation

Preparation of land: The area of planting should be completely cleared of all vegetation including root stocks and herbs/shrubs; it should thoroughly be prepared by ploughing and harrowing.

Spacing: 4 m x 4 m

Pit size: 45 cm x 45 cm x 45 cm

Fertilizer application: Lime should be applied on the basis of lime requirement of soil; however, in absence of lime requirement data 66 kg of dolomite/bigha should be added to the soil. Application of 5 kg of FYM should be added in each pit. A fertilizer dose of 45:15:30 g of NPK/plant should be applied 3 months after planting. Apply 45 g of N/plant after 6 months when the crop is in bearing stage.

Planting: Hard wood cutting are planted directly in the field in pits during onset of monsoon. Every precaution should be taken to avoid over-watering or water stagnation at the base of the cuttings in order to prevent rotting.

Irrigation: Irrigate before planting and subsequently at monthly interval according to soil type.

Tending Operation

Weeding: During the 1st year 3 weeding are required.

Pollarding, coppicing, lopping or pruning: An overgrown tree may be cut back to 1-2 m above ground level to induce juvenility. In case of coppice shoots, only 2-3 shoots should be retained per stool. By training and pruning 3-4 times during vegetative phase a strong frame work with bushy shape may be obtained to maximize fruit and leaf production. Pruning should be undertaken before the month of August as flowering starts in November-December.

Others: Protection against grazing, browsing and fire is required for establishment and proper growth of drumstick. It is necessary to pinch the terminal bud on the central leader stem when it attains a height of 75 cm. This will promote the growth of many lateral branches and reduce the height of the tree.



Sajina tree (bearing)

Tree Protection

Insect-pest: In Assam, several insect pests are seen to attack Sajina, including various caterpillars such as the bark-eating caterpillar, the hairy caterpillar or the green leaf caterpillar. Occurrence of hairy caterpillars on the tree trunks is main deterrent for its inclusion in kitchen garden.

Management: Use flame torch when the caterpillars settle on the tree trunk or spraying of contact insecticides.

Disease: No serious disease has been recorded so far in this region but, of late, pod rot is turning out to be a serious problem in the southern states.

Orientation

Boundary/in field/on bunds/homestead

Suitable intercrop

Okra, tomato, french bean, cowpea or flower can be cultivated as intercrops in young Sajina plantations.

Yield/ Annual Return including Tree Productivity

Plants raised from cuttings give flower in that very year but 20-30 fruits can be harvested in the second year and increases to 200- 300 nos. in 4- 5 years. A fully developed tree yields 600-800 pods annually.

Economics

Estimation of production economics shows that one hectare of well grown drumstick plantation can fetch net return as high as Rs.2.0-2.5 lakh per year in Assam.

Use

It is widely cultivated for its young pod, flower and leaf which are used as vegetables and for traditional herbal medicine. Drumstick leaf powder is effective as soap for hand wash due to its anti-septic and detergent properties. The oil can be used as a food supplement, as a base for cosmetics, for hair and skin care and for fine machine lubrication. The seed cake may be used as fertilizer or as a flocculent to purify water. Leaves, shoots and pods also make a high quality fodder. The coarse fiber from bark is used for making ropes. Bark exudes a gum, used in calico printing as a substitute for tragacanth.

Sajina leaf possess more beta- carotene than carrot, more calcium than milk, higher iron content than in spinach, more vitamin C than oranges, richer in protein than peas and potassium content can be compared with in bananas. Leaves are packed with powerful of antioxidants called flavonoids, includes quercetin, kaempferol, and a host of other antioxidants. Every part of the tree has medicinal use such as natural antibiotic and anti inflammatory properties, diuretic, anthelmintic, cardiac tonic, abortifacient, cures sexual disorders, aids in child birth, for treating liver and spleen disorder. Flowers are used to heal inflammation of tendons and abscesses. Flower juice improves quality of lactation and is used in urinary problems. Seed oil is used against hysteria, scurvy, prostate problems and bladder trouble.

Timber can be used only for floats, toys, sandwiched materials, firewood, etc.

Environmental Benefit

The flowers are valuable bee forage. Drumstick has a high rate of carbon dioxide absorption, which makes the species an important resource for the mitigation of climate change for which the species could be used in afforestation programme. In addition, the environmental contribution of the species are fighting malnutrition, checking soil erosion, improving soil fertility and purifying water bodies.

Way Forward

As an agroforestry component in the homesteads, uplands and in hillocks, drumstick tree has tremendous potentiality in Assam either as boundary plantation or as block plantation with intercrop of vegetables and flower crops in the interspaces.

Sandan (*Santalum album* L.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Sandalwood
Trade name:	Sandalwood
Assamese name:	Sandan
Family:	Santalaceae

Introduction

Santalum album L. is a thorn less, small-sized, fragrant, evergreen tree growing up to 6-8 m height. It is a hemi-parasitic plant and parasitizes the roots of other tree species.

Habit and Habitat

Sandan is adapted to wide range of soil; successfully grows in marginal land like sandy or gravel well drained soils. It grows in locations having the temperature range from 0 to 38 °C and the annual rainfall of 500mm to 3000 mm. It grows up to 900 m above msl.

Silvicultural Character

In its early stage Sandan needs partial shade and thrives well under cover of thickets of scrub. In middle and later life it is intolerant to heavy overhead shade, but is often found growing under comparatively light cover. Root suckers are exposed or cut through or where the parent tree has been felled and the stump grubbed up. Young trees coppices fairly well. The species is sometimes killed by prolonged drought. It often suffers from bark scorching caused by insolation and possibly to some extent by wind. Leaves are readily browsed by domestic animals.

Distribution

Sandan is native to semi-arid areas of the Indian sub-continent. It is also planted in China, Sri Lanka, Indonesia, Malaysia, the Philippines and Northern Australia. It is parasitic in nature during growing stage. The principal sandalwood tracts in India are Karnataka and adjoining districts of Maharashtra, Tamil Nadu and Andhra Pradesh. In Assam rain shadow belt (Nagaon, Hojai, Karbi Anglong, Dima Hasao and Golaghat districts) is the most suitable area for growing Boga-Sandan. Besides, the species grows luxuriantly in some pockets of Darrang, Sonitpur, Biswanath and Lakhimpur districts.

Phenology

Leaves are opposite, simple, light green-coloured above and paler beneath, thick, glabrous on both sides and have a 1 cm long petiole, leaf, blade is elliptic, apex is acute (sometimes obtuse), base is attenuate and the margins are entire. The venation of the leaf is reticulate with a

prominent midrib. Flowers auxiliary or terminal paniculate cymes, perianth-tube cup-shaped, 2 mm long and 2.5 mm wide, perianth-lobes are composed of 4 petals 2 mm long and 1.5 mm wide, androecium is composed of 3-lobed stigma at the tip, ovary is globose, 1 mm across and 1-loculed. Fruit is a subglobose or ovoid drupe, 1-1.5 cm long and 1 cm wide and contains 1 stone.



Sandan tree

Parasitism

Sandan is obligate root parasite. It draws part of its nutrition (mainly Ca and K) from the soil and part of its nutrition (mainly N and P) from host plants through haustoria developed with secondary host plant. For Assam conditions plants like Bhatghila (*Oroxylum indicum*), Amlakhi (*Emblia officinalis*), Karach (*Pongamia pinnata*), Coconut (*Cocos nucifera*), Agarwood

(*Aquilaria malaccensis*), Mahaneem (*Azadirchta indica*) and Pachatia (*Vitex negundo*) may be used as secondary host plants.



Sandan in Homestead

Propagation Technology

Natural propagation: Seed

Artificial Propagation: Seed, Root sucker, branch cutting, cleft grafting and tissue culture

Seed from ripe fruits is collected between Nov to Feb. About 4000-5000 seeds (1 kg) produce about 1000 healthy seedlings.

Pretreatment: Burring bags having sandalwood seed in cow-dung heaps for 20-30 days enhances germination.

Nursery technology

Seed sowing: Seeds are sown on raised and well prepared bed in line. Sandalwood seed show about 30-40 % germination. Fresh seeds take about 20 days to germinate and continued another 25-30 days to complete. Healthy seedlings at 2-4 leaf stage are transferred to previously fill up black poly bag of size 30 cm x 14 cm. Arhar (*Cajanus cajan*) or Tuloxi (*Ocimum sp.*) seeds sown to serve primary host for better growth of sandalwood seedling. Poly bag should contain soil mixture of ratio 2:1: 1 (Sand: Garden soil: FYM). Poly bags are placed in rectangular beds with proper shade and irrigation. It is important that there should not be root distortion before planting; here lies the importance of using air punned seedlings or seedlings raised in poly bags along with primary host.

Cultural Operation

Land preparation: Land should be completely cleared of all vegetations followed by ploughing and harrowing.

Planting time: Planting should be done during Mar to Jun with onset of pre monsoon shower. However, planting may be carried out throughout the year if proper irrigation facility is available.

Spacing: 4 m x 4 m

Pit size: 45 cm x 45 cm x 45 cm. Pits are dug for both sandalwood and secondary host plant and left for 15-20 days exposing to sunlight.

Manures & fertilizers: Lime @ 200 g/pit should be added and mixed in the pit before 1 month of planting. FYM @ 5 kg/pit should be applied before planting. After 4 month of planting when the seedlings are well established, organic manures like compost or FYM @ 2 kg/plant is applied and mixed with the soil around crown of the plant. Application of FYM @ 3-4 kg/plant at 8-9 month of planting is beneficial. Second year onwards, manuring of FYM @ 4-5 kg/plant twice in a year, before and after monsoon followed by light earthing up, may be done.

Planting: Pits are filled up in such a way that water does not accumulate in pit. After filling up the pits a well grown perennial species as host plant like agar tree or any other suitable host tree seedlings should be planted. It is advisable to establish the host plant prior to plantation of sandalwood tree. After two months sandalwood seedlings are planted in the pit. Gap filling should be carried out preferably during the same year.

Tending Operation

Irrigation: For quick initial growth, irrigation may be done at 15-20 days interval during drought period in winter.

Weeding: During first year 2-3 weeding is required especially in monsoon period.

Soil working: Soil working is an important operation which should be done to a radius of 50 cm once in 6 months.

Lopping: Host plant is lopped to provide enough light to sandalwood seedling.

Fencing: Fencing is required to protect the seedlings against browsing by animals.

Rotation: The sandalwood tree grown from seed may be harvested at the age of 15th year onwards. However, a tree grown from coppice may be harvested at the age of 10th year.

Harvesting

Harvesting is usually done during winter by uprooting the tree as the root possesses the essential oil content in high amount.

Tree protection

Insect-pest:

Insect defoliator: Insect-pests like *Sympiezomias cretaceous*, *Holochlora albida*, *Teratodes monticollis*, *Letana inflata*, *Cryptothelea cramerii*, *Acanthopsyche moorei*, *Pteroma plagiophleps*, etc. are common insect-pest defoliating the plants in nursery as well as in the field.

Management: Spraying 0.2–0.3% Chlorpyrifos or Quinalphos or any contact insecticide.

Sucking pest: Insect-pests like *Ceroplastes ceriferus*, *Saissetia* sp., *Inglisia bivalvata*, *Tachardina lacca*, etc. are common sucking pests.

Management: Spraying of Monocrotophos (0.02–0.05%) or Quinalphos (0.5%) or Chlorpyrifos (0.2–0.3%) give good results.

Disease:

Pre-emergence rot and damping off (by *Fusarium* or *Phytophthora* or *Rhizopus* spp.)

Management: (a) Selection of disease free seeds, (b) seed-dressing with organomercuric compound, (c) good drainage.

Fusarium wilt (*Fusarium* or *Phytophthora* species) followed by nematodes

Management: (a) Drench the potting medium with copper fungicide and nematicide (Bordeaux mixture and Quinalphos or Phorate), (b) good drainage.

Orientation

Boundary/in field/ on bunds/ homestead

Suitable Intercrop

Oilseed and pulse crops can be grown as intercrop up to 3rd year of plantation. Thereafter, some shade tolerant crops such as Patchouli, Sarpagandha, Satmool, Ginger, Turmeric, pineapple, etc. can be cultivated as intercrop.

Yield/Annual Return/Tree Productivity

Average yield of heartwood of sandalwood in Assam is in the range of 20-30 kg after 20 years of plantation. On steam distillation, the essential oil production is about 1.5 kg. Additionally, after completion of crop cycle of sandalwood, a sizable production of host plant is obtained depending upon the species selected.

Economics

In foothill area of central Assam heartwood takes place 9th year onwards. After 15 years of planting the heartwood production of sandalwood is about 3097 kg/ha which fetches a net return of Rs. 42.80 lakh/ha with B:C ratio of 12.23. Income will be more if the product is sold after value addition. Further delay in harvesting will increase the yield.

Use

Sandan is heavy, hard, durable, strong, resistant to termites attack and strongly aromatic as it seasons. Heartwood is much used for ornamental and carving work. Formerly, in China the most expensive coffins were made of sandalwood, while in India it was the preferred wood for funeral pyres. The dust of sandalwood is utilized for Agarbatti manufacturing. Oil is used as flavouring agent in a range of foods including chewing gum, ice cream and bakery products. It is a basic component of countless perfumes, cosmetics and toiletries. The oil has been widely used in folk medicine for treatment of common colds, bronchitis, skin disorders, heart ailments, general weakness, fever, infection of the urinary tract, inflammation of the mouth and pharynx, liver and gallbladder maladies. It possesses anti microbial and antioxidant properties. Leaves can be used as green manure.

Environmental Benefit

Intervention of Agri-Silviculture and Horti-Silviculture systems helps in recycling of nutrients and improving soil health. Moreover, the tree along with the host plant has immense potentialities of carbon fixation. It is sometimes grown as an ornamental and as a low branching wind-break.

Way Forward

Sandan based Agri-Silviculture/Horti-Silviculture agroforestry system has tremendous scope as boundary plantation, block plantation and homestead especially in the foot hill region of rain shadow areas of Assam.

Sisu (*Dalbergia sissoo* Roxb. ex DC.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Indian Rosewood
Trade name:	Shisham, Sissoo, Sisu
Assamese name:	Sisu
Family:	Fabaceae

Introduction

Dalbergia sissoo Roxb. ex DC. is a nitrogen fixing medium to large sized fast growing deciduous tree with light spreading crown; it grows up to 30 m height and 2-3 m diameter. The species is categorized as A-II timber.

Habit and Habitat

Sisu is the most suitable for the moist tropics and subtropics and growth is most prolific in areas where there is considerable soil moisture, but not in waterlogged soil. It is most typically found on seasonally inundated alluvium and on eroded/gullied areas in the sub-Himalayan tract from Jammu to Assam and the Himalayan Valleys, in river-beds, along water channels and on alluvial flats subject to annual floods. The optimum temperature of 18-24°C, annual rainfall of 1000-1700 mm, and altitudes up to 1000 m above msl. is suitable for growth of the species. It prefers well drained soils with light/medium texture which may be composed of sand, pebbles and boulder alluvium. The species needs neutral to acidic soil with adequate moisture. In heavy soil or soil with high water table Sisu suffers from wilt diseases.

Silvicultural Character

Sisu is a strong light demander and require full overhead light from the seedling stage. It is definitely frost hardy but is affected by severe frost up to pole stage. In earlier stages the species is sensitive to drought but later on it becomes drought resistant. It coppices profusely up to about 20 years age and produces profuse root suckers. Sisu cannot withstand fire. Due to well developed root system it is wind firm species. The species is susceptible to damage by browsing with domestic animal.

Distribution

Sisu is native to the Indian Sub-continent and Myanmar; however, it is naturalized into Africa, Australia and southern USA.

Phenology

The leaves are compound, imparipinnate and alternate, with rachis 3.5-8 cm long, swollen at the base. There are 3-5 leaflets, each 3.5-9 x 3-7 cm; leaflets alternate, broadly ovate, conspicuously

and abruptly cuspidate at the apex, rounded at the base, entire, coriaceous, pubescent when young and glabrous when mature. The terminal leaflet is larger than the others, and there are 8-12 pairs of veins in the leaflet. The inflorescence of *D. sissoo* is an axillary panicle 3.5-7.5 cm long, with small flowers, 7-9 mm long, white to yellowish-white with a pervasive fragrance, sessile, papilionaceous and hermaphrodite. The standard petal is narrow at the base and forms a low claw; wing and keel petals are oblong. Pods are 4.5-10 x 0.7-1.5 cm, linear-oblong, indehiscent, stipitate, glabrous, apex acute, reticulate against the seeds, and usually 1-4 seeded. Seeds are kidney-shaped, variable in size (8-10 x 4-5.5 mm), pale brown, brown to brownish-black, reniform, compressed, with papery testa.

It normally flowers between Feb and Apr. Following the appearance of buds the flowers take from 13-15 days to come into full bloom and further 20-25 days develop pods.

Propagation Technology

Natural propagation: Seed, coppice, root sucker

Artificial Propagation: Seed, entire transplanting, stump planting, root sucker and branch cutting and tissue culture

Usually stump planting is the most common, cheap and reliable method giving almost 100% success and better growth.

Nursery Technology

Pre-treatment: Pre-treatment of seed is not required; however, soaking of broken pods in water for 12 - 24 hours at room temperature accelerates germination.

Nursery site and seed sowing: Well drained sandy loam with gently sloping terrain is suitable for preparing nursery. In moist location the beds are raised to a height of 30 cm from ground level to prevent water logging. Mature pods are broken into 1-seeded pieces and sown in nursery bed in 15 cm x 5 cm spacing. Germination of fresh seed takes 7 - 21 days; germination is almost 100%. Shading is recommended during the hottest hours of the day during the germination period.

For avenue planting larger seedlings is required; seedlings are pricked out again when 8 months old at the spacing of 22.5 cm x 22.5 cm. These large plants are planted out with ball about 2 m height at the end of 16-18 months. For other purposes stump planting is preferred.

Stump preparation: 6-8 month old seedling is uprooted from nursery bed; stem and roots are pruned keeping 20 cm stem and 10 cm primary root.

Cultural Operation

Land preparation: Plough the land and level it properly. Mark the areas for pit digging by alignment and staking.

Pit size: 45 cm x 45 cm x 45 cm.

Spacing: 2.5 m x 2.5 m. It can also be raised along with agricultural crops at a spacing of 4 m x 4 m. Boundary plantation of 1-2 rows at the spacing of 2 m x 2 m is adopted.

Planting time: Best planting season is monsoon for Sisu; preferably after the first shower.

Fertilizer application: Apply 5 kg of FYM in pit.



Sisu tree

Tending Operation

Weeding: First weeding should be done soon after the stumps sprout or seeds germinate; during 1st year 2-4 weeding is required. Depending upon the luxuriance of weed growth 1-2 weeding is required in the 2nd year. In the 3rd year 1 weeding may be needed. In irrigated plantation 1-2 weeding is needed at the end of the 1st year or early 2nd year. If grown from coppice, coppice shoots should be decreased to 2-3 no./stool.

Soil working: During 1st year soil working is needed along with the last weeding.

Thinning: Thinning should be done at the ages of 3, 6, 10, 15, 20, 40 and 50 years.

Irrigation: 1-2 irrigations are necessary in first and second year during prolonged drought period.

Rotation: Matured marketable wood is obtained in 20-25 years. However, to produce large diameter logs with a high percentage of valuable heart wood, a rotation age of 60 years is commonly followed.

Tree Protection

Insect-pest:

Insect defoliators like *Plecoptera reflexa* (a defoliator), *Dichomeris eridans* (leaf binder), *Brachytrupes portentosus* (causing nursery damage)

Management: Spraying 0.2–0.3% Chlorpyrifos or Quinalphos or any contact insecticide
Termites attack young trees

Management: Apply 0.2-0.3% Fipronil or Chlorpyrifos or Imidacloprid

Disease:

Leaf diseases include the powdery mildew fungus, *Cercospora sissoo* (leaf spot), *Colletotrichum sissoo* (leaf blight fungus)

Management: Selection of disease free seeds, seed-dressing with organomercuric compound and good drainage

Fusarium solani dalbergiae (leaf wilt)

Management: Drench the potting medium with copper fungicide

Wood pathogens include *Daedalea flavida* (wood rot fungus) and *Fomes durissimus* (stump rot fungus)

Management: Apply boric acid or borate

Parasitic plant:

Parasitic plants cause considerable damage to Sisu includes *Loranthus longiflorus* and *Tapinanthus dodoneifolius*; in alluvial forests, climbers like *Dregea volobilis*, *Cryptolepis buchanani* and *Acacia pennata* cause the same damage.

Management: Mechanical removal of parasitic plants.

Orientation

Boundary/block plantation/ homestead /roadside plantation/wasteland



Sisu at pond dyke

Suitable intercrop

Sisu is suitable for plantation in the boundary of crop field. Intercropping of different field and horticultural crops in the plantation at a wider spacing of 4 m x 4 m can be done.

Yield/ Annual Return including Tree Productivity

Tree productivity of Sisu is increased with advancement of its maturity. The productivity at different ages has been shown as follows:

Year	Tree productivity	
	m³/ha	m³/ha/yr
10	10	-
20	100	5.0
30	210	7.0
40	280	7.0
50	370	7.5
60	460	7.5

Economics

Gross return per year is Rs. 1, 89,000/- per ha per year in 30-50 years of plantation.

Use

Sisu wood is hard, strong, elastic and durable with decorative grain. It is suitable for all types of construction works, e.g. for door and window shutters, frames, flooring and paneling. The timber is widely used for cabinet making, vehicle bodies, railways carriages & wagons, boat building, etc. Wood of Sisu is suitable for making shoe lasts, carving, veneer and plywood (aircraft grade). It is excellent for high-class bentwood furniture, walking-sticks, umbrella handles, agricultural implements, electric casing, tool handles and other bentwood articles. Pulp from the wood is suitable for paper making. It is highly valued as firewood and for charcoal production. A non-drying oil which is suitable as a lubricant for heavy machinery can be obtained from the heartwood. Leaves are medium quality cattle feed.

Environmental Benefit

Being a nitrogen-fixing species Sisu is widely used as a shade tree in agroforestry systems. It is acknowledged for its environmental benefits, increasing soil fertility and reducing soil erosion. It is grown for reforestation of eroded soils, as a soil improver besides providing mulch, windbreak and shelterbelt. It has an unusual amenity to use as a host for orchids. It may be planted as one component of a multi-tiered home garden system, where it contributes several products. Sisu is widely used in urban and roadside plantation in the Indian subcontinent and in other parts of the world.

Way Forward

Sisu based Agri-silviculture/ Horti-Silviculture system has tremendous scope throughout the state especially in homestead, waste land, road side and eroded areas.

Teak (*Tectona grandis* L.f.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Indian Oak, Teak
Trade name:	Teak
Assamese name:	Chegun
Family:	Lamiaceae

Introduction

Tectona grandis L.f. is one of the most important timber trees of the world and commonly known as “The King of Timber”. In Assam, this is the only timber species designated as A-I category timber; therefore, most popular among the common people. In Assam, Teak was first successfully tried in 1872 at Kushi in Kamrup district followed by Makum in Dibrugarh district.

Habit and Habitat

Chegun is a large deciduous tree with a rounded crown, a tall clean cylindrical bole and often buttress at the base; it grows up to 40 m tall with grey to grayish brown branches. It grows in a variety of habitats and climatic conditions from arid areas with only 500 mm of rain per year to very moist forests with up to 5000 mm of rain per annum. However, in the most suitable areas annual rainfall is 1250-1650 mm with a 3-5 month dry season. It grows up to 1200 m above msl; however, its best growth is achieved at about 600 m and below. In its natural habitats, maximum temperature rises to 48⁰C and minimum temperature drops to 2⁰C. It grows well on the soils derived from granite, gneiss and schist like many soils of the Brahmaputra Valley, derived from the Assam Hills. Deep alluvial soil with deep water table is suitable for the growth and development.

Silvicultural Character

Chegun seedling is a strong light demander; it cannot tolerate suppression at any period of its life and requires complete overhead light as well as a fair amount of side room for its proper development. It is sensitive to frost and prolonged drought. It coppices and pollards vigorously up to about middle ages. Because of these characteristics Chegun escapes damage from frost, drought, grazing and fire. However, seedlings and saplings killed back by fire.

Distribution

Chegun is native to South and Southeast Asia mainly India, Sri Lanka, Myanmar, Indonesia, Malaysia, Thailand and northern Laos; but it has been naturalized and is now cultivated in many countries of Africa and Caribbean.

In India in natural habitat its upper limit is Rajasthan (24⁰42' N latitude) and UP (25⁰33' N latitude); thereafter, it drops towards south and goes towards Mahanadi. However, later on it was raised in UP, Odisha, Bengal, Andaman and Assam.

Areas nearby natural Xal forest in Central Brahmaputra Valley Zone and Lower Brahmaputra Valley Zone are the most favourable for segun plantation in Assam.



Teak block plantation

Phenology

Leaves are large, papery and often hairy on lower surface, ovate-elliptic to ovate in shape, 15-45 cm long, 8-23 cm wide and are held on robust 2-4 cm long petioles. Leaves margins are entire. Flowers are small, white and fragrant; arranged in dense panicles at the end of the branches. Panicles are 25-40 cm long and 30 cm wide. Corolla tube is 2.5-3.0 mm long and 2 mm wide with obtuse lobes. Flowering season is Jun to Aug and fruit sets in Sep-Dec. Flowers are primarily entomophilous (insect-pollinated), but can occasionally be anemophilous (wind-pollinated).

Propagation Technology

Natural propagation: Seed

Artificial Propagation: Seed, entire planting, stump planting, grafting, rooted stem cutting and micro propagation

Nursery technology

Seed treatment: Germination percentage of teak is highly variable and varies from 10-70% depending upon the source of seed. Fruits being hard nut, needs pre-sowing treatment to hasten germination which may be done by any one of the following methods:

- a) Fermentation or cow-dung slurry treatment for 2 weeks or more till the seeds show sprouting;
- b) Weathering or alternate soaking and drying for 2-3 days each for a week and drying for 2-3 days each for a week and sometimes for nearly 2-3 months;
- c) Immersion in water at normal temperature for 48 hrs to several days;
- d) Exposing the seeds to the weather (i.e. sun and rain) for few months to a whole year in open;
- e) Immersion in boiling water which is then allowed to cool down;
- f) Scorching in light fire of leaves and grass;
- g) Alternate layers of Teak leaves and seeds in pit, final covering of 15 cm of earth; watered on alternate days through inserted hollow bamboo pipes for about 10 days;
- h) Acid treatment.

Seedbed preparation and seed sowing: Well drained sandy loam with gently sloping terrain is suitable for preparing nursery. In moist location like Assam the beds are raised to a height of 30 cm from ground level to prevent water logging. In dry zones, beds are made flush with the ground level. Five kg seeds are commonly used for 12 m² bed. Standard size of bed is 12 m x 1.2 m. Treated seeds are sown 7.5 cm x 7.5 cm in lines, about 1 cm deep, between Feb and May. Germination takes place in 15 - 30 days. Seedlings are pricked out in transplant beds during the first rains at a spacing of 15-20 cm x 15-20 cm. About 1 year old seedlings are fit for preparing stumps; 2-4 months seedlings are suitable for planting out entire.

Stump preparation: About 1 year old seedling with 1.0-2.0 cm collar diameter is uprooted from nursery bed; stem and roots are pruned keeping 30 cm stem and 15 cm primary root.

Cultural Operation

Land preparation: After removing the weeds, shrubs and stones, ploughing and leveling of land should be done. Mark the areas for pit digging by alignment and staking.

Pit size: Pit size of 45 cm x 45 cm x 45 cm is ideal.

Spacing: Teak can be planted at 2 m x 2 m, 2.5 m x 2.5 m or 3 m x 3 m. It can also be raised along with agricultural crops at a spacing of 4 m x 4 m or 5m x 1 m. Boundary plantation of 1-2 rows at the spacing of 2 m x 2 m is adopted.

Planting time: Best planting season for teak wood farming is monsoon; preferably after the first shower.

Fertilizer application: Apply 5 kg of FYM in pit. Fertilizer application @ 67-89 g of Urea, 94-125g of SSP and 25-33 g of MOP/plant should be applied every year from 2nd year up to 5th year. The same amount of fertilizer may be applied in 8th and 11th year after plantation. Half of the chemical fertilizer should be applied during Mar-Apr and rest amount in Sep-Oct.



Teak at boundary

Tending Operation

Weeding: In the first year, at least 3 weedings are needed during Jun-Aug; in second year 2 weedings are required and in the 3rd year only one weeding is necessary. In the 1st year lines are clean weeded. Second year weeding include climber cutting, cutting back of bad stems and removal of double leaders. Climber cutting is done in the 3rd and subsequent years.

Soil working: Soil working in the 1st year during Oct-Nov enhances the growth of plant.

Irrigation: 1-2 irrigations are necessary up to 3rd year during prolonged drought period.

Pruning: Pruning is an important practice in the cultivation of Teak in farm land; pruning decides the growth, clear bole and intercropping ability. Pruning of side branches is usually carried out in every six months. The pruned branches can be used as fire wood.

Thinning: The thinning in block plantation of Teak is an important practice to enhance the production of saw log. First thinning at 5th year and second thinning at 10 th year after plantation is suggested so as to keep only 25 % trees for better growth. The alternative trees in the row are to be thinned, to avoid competition between the trees and maximize the growth. The thinning operation may also be done at the age of 18, 28 and 40 years.

Rotation: For sawn timber wood of Teak become mature at the age of 50 years. However, the stem diameter increases up to 120-130 years.

A tree of 14-15 years can be utilized for poles. Trees removed at the time of thinning after 15th year are mostly utilized for this purpose.

Tree Protection

Insect-pest: Teak defoliator and skeletoniser (*Hyblaea puera* and *Eutectona machaeralis*) cause extensive damage to young plantations in teak. Root rot due to *Polyporous zonalis* is also common in teak plantation. Pink disease fungus causes cankers and bark flaking. Powdery mildew caused by *Olivea tectonae* and *Uncinula tectonae* leads to premature defoliation.

Management: Fresh leaf extracts of *Calotropis procera* (Akon), *Datura metal* (Dhatura) and *Azadirachta indica* (Mohaneem) are found to be most effective against teak skeletonizer. This method is of immense importance in the insect pest control considering its harmless and pollution free implication on the environment, further avoiding the operational and residual hazards that involve in the use of organic insecticide (e.g. Neemacin 1500 ppm @ 4ml/lit water) and inorganic insecticide (e.g. Quinalphos 25 EC @ 0.05%).

Disease: Pink disease (*Corticium salmonicolor*), leaf spot disease (*Phomopsis sp.*), wilting disease (*Colletotrichum gloeosporioides*), stem rot (*Burkholderia solanacearum*) are the important diseases of teak.

Management: Soil drenching with copper fungicide and nematicide (Bordeaux mixture and spraying Mancozeb @ 0.25 % or Carbendazium @ 0.1 %), effectively control leaf spot diseases.

Orientation

Boundary or block in field/on bunds/in homestead

Suitable intercrop

In boundary plantation any field or horticultural crop may be grown as intercrop. However, in block plantation intercropping in Teak plantation during the initial two years of planting is a common practice where there is a demand for cultivable land. The common intercrops are *Ahu* rice, chilli, maize, wheat, sesame and various vegetables. Crops like *Sali* rice, sugarcane, banana, cucurbits, etc. should never be selected as intercrops. To grow intercrops for more years the spacing should have to be increased. In between two rows of Teak tree crops like Subabul, Glycidia, etc. can also be grown; however, frequent lopping of intercrop may be required.

Yield/ Annual Return including Tree Productivity

Each teak tree yields 0.283 - 0.425 m³ (8 - 11 cft.) wood /tree in about 14 years and 0.596 - 4.241m³ (16-115 cft.) wood/tree in 50 years.

Economics

The wood of Teak fetches at least Rs.8,000 /tree in 14 years to the highest of Rs.52,829/tree in 50 years.

Use

Teak wood is moderately hard and extremely durable; its high oil content, high tensile strength and tight grain make it particularly suitable for weather resistance. It is easy to air-season, easy to work and saw, peel on a rotary lathe; makes excellent plywood. This species is resistant to termite attacks and damage caused by other insect-pest. It is unique for ship building and extensively used for making bridges, buildings, doors, windows, piles, poles, railway carriages, boat decks, decorative paneling, carving, cutting board, indoor flooring, ordnance works, general carpentry, countertops and as a veneer for indoor furnishings. Teak is used extensively in India to make doors and window frames, furniture, and columns & beams.

Environmental Benefits

It is an ideal choice for large-scale afforestation programmes. Intervention of Agri-silviculture system helps in recycling of nutrients and improving soil health. Moreover the tree has immense potentialities of cleaning environment by fixing carbon.(above ground C stock of 1.5229 Mg/tree in 50 years).

Way Forward

Chegun based Agri-Silviculture/Horti-Silviculture agroforestry system has tremendous scope especially in the foot hill region, hills and hillocks and flood free plains.

Titachapa (*Michelia champaca* L.)

Agroforestry Model:	Agri-Silviculture, Horti-Silviculture
Common Name:	Champaca
Trade Name:	Champaca
Assamese Name:	Titachapa
Family:	Magnoleaceae

Introduction

Michelia champaca L. is an evergreen to semi-deciduous and medium to large sized timber tree up to 50 m tall. It is categorized as A-II timber.

Habit and Habitat

Titachapa grows well in the areas having maximum shade temperature from 37.5°C - 47.5 °C, absolute minimum temperature 0 °C to 17.5 °C, rainfall 2250 – 5000 mm and relative humidity 80 – 90% in Jul and in Jan 60 – 80 %. It performs well along foothills up to an altitude of 1500m above msl. It is well suited in sandy loam, moist, deep, well drained and fertile soil.

Silvicultural Character

The tree is a light demander, fast growing tree and coppices well up to a fair size; it does not produce root sucker. Young plants are not affected by drought; however, it does not tolerate water logged condition and is highly sensitive to fire. The tree is frost hardy. Hailstorms, which occur in Mar-Apr, destroy the flowers; the young fruits are damaged by birds, mice and rodents in large quantity.

Distribution

The tree is wide spread all over tropical Asia. It is extensively cultivated in many parts of India and Myanmar. In India it is wild in the forests of the eastern sub Himalayan zone from Nepal eastwards along the foothills up to 900 m, including West Bengal and Assam. It is also found in the Western Ghats from Karnataka to Kerala.

Phenology

Bole straight, cylindrical, up to 200 cm in diameter, without buttresses; bark surface smooth, grey to greyish-white, inner bark fibrous, yellow to brown, crown conical to cylindrical. Leaves simple, alternate, spiral; petiole 1-3 cm long, stout and planoconvex in cross section; lamina 9.5-25 x 3.5-9 cm, elliptic-lanceolate, apex acuminate with twisted acumen, base acute to attenuate, margin slightly undulate, glabrous, chartaceous; midrib nearly flat above; secondary nerves 12-16 pairs; tertiary nerves closely and strongly reticulate. Flowers solitary, axillary, large, yellow, petals 6-21, in 3-6 usually subequal whorls, fragrant. Follicles, warty, 2-3 cm long, arranged as

spike, dehiscing dorsally; seeds 1, scarlet; stamens many, anthers with a short to prominently elongated connective; gynoecium stipitate, with spirally arranged, free or connate carpels containing many ovules. Fruiting carpels are dehiscing along the dorsal surface when free or fused and forming a fleshy or woody syncarp. Seed hanging from its funicle.



Titachapa tree (with seed)

Propagation Technology

Natural propagation: Seed, coppice

Artificial Propagation: Seed, coppice

Nursery technology

Seed sowing: Ripe fruits are collected from the trees in Aug-Sep. Seeds should be cleaned and dried in the shade. The seed should be sown within two weeks of collection as it loses its viability very rapidly. It is desirable to mix seed with red lead to prevent attack by red ants and rats. Seeds are sown in Aug – Sep in shaded nursery beds for protection against the sun, either broadcast or in drills 8-10 cm apart, with a thin layer of earth sprinkled over the seeds. The shade is removed by Jun of the following year. Thatch grass or brushwood may sometimes be spread over the bed to hasten germination.

Cultural Operation

Land preparation: The area of planting is completely cleared of all vegetation including removal of all root stocks and bushes. Plough the land thoroughly and level it properly. Mark the areas for pit digging by alignment and staking.

Spacing: The spacing for block plantation adopted is 2.4 m x 2.4 m in Assam. Planting single row or double rows in crop field boundary may also be adopted at a spacing of 2.4 m x 2.4 m.

Pit size: 45c m x 45cm x 45 cm

Fertilizer application: Well rotten farm yard manure like cow dung, garden compost, vermin compost or any manure made from green leaves can be used @ 5kg/pit at the time of planting.

Planting: The most successful method of propagating champ is by planting out nearly one year old seedlings at the break of the monsoon of the following year. Planting out with ball of earth or with naked roots, though success chiefly depends upon congenial planting weather. The ball of earth should be 7.5 to 10cm in diameter and 15cm long. Winter planting with proper irrigation is also successful and is recommended for filling up casualties in the very first winter.

Stump planting of 2 years old nursery plants is also a successful method; however, pruning off numerous shoots grown from each stump should be done carefully.

Tending Operation

Mounding: Titachapa is very sensitive to water stagnation; hence the ground around seedlings should be worked up into small mounds, once or twice during monsoon.

Weeding: For initial 2-3 year only weeding is required.

Thinning: The first thinning in well-stocked plantations will normally be required in the 5th year if the spacing is about 2.4 m x 2.4 m.

Rotation: For sawn timber 50 years is usually recommended; however, it may be extended up to 125 years.



Titachapa block plantation

Tree Protection

Insect-pest: Titachapa is subject to the attacks by champaca bug (*Urostylis punctigera*), causing appreciable damage in pure plantations and it produces five generations in a year. The nymph sucks sap of newly formed leaves and tender shoots resulting weathering of plant. The adult sucks the petioles and green shoots, as also the main stem of the young tree. Because of its size and longer life, the adult causes more damage than the nymph.

Management: Mix plantation of champ with other non-susceptible species will appreciably reduce pest infestation. Spraying with a suitable mixture, such as nicotine sulphate 1 part and soap 1.8 kg in 450 liters of water is helpful.

The natural bio-control agents of the bug such as *Pachyneuron pentatomivora*, a parasite and *Calvia tricolor* a predator can be introduced to control *Urostylis punctigera*. Red ants collected and released on plantation will kill the bugs of *Urostylis punctigera*.

Disease: *Prociphilus micheliae* causes leaf curling in trees and *Phomopsis micheliae* causes a leaf spot disease.

Management: Leaf spot disease can be controlled by spraying Mancozeb @ 0.25 % or Carbendazium M-45 @ 0.1 %.

Parasitic plant: In Assam, Loranthus attack is a major problem in some plantations.

Management: Mechanical control is the only way to get rid of Loranthus attack. Early treatment consists in removing affected branches. At later stages the parasite can be killed by cutting off the extruding stem 1½ - 2 inch. above the point of emergence and treating the cut surface with a 5% common salt solution applied in an absorbent pad.

Orientation

Boundary/in field/on bunds/homestead

Suitable intercrop

Field and horticultural crops can be grown as intercrop in the boundary plantation.

Yield/ Annual Return including Tree Productivity

The total yield per hectare is around 275 – 325 ton/ha.

Economics

The wood of champ fetches about Rs.8000/ton.

Use

Titachapa timber is lustrous, smooth and easy to saw. It has a finely textured, dark brown and olive-colored wood, which is used in making furniture, veneers and cabinetry. It is widely used for construction purposes. Titachapa wood is accepted as suitable for the manufacture of Grade-I commercial moisture proof plywood and tea-chests. It is also suitable for heavy packing cases, superior type boxes, battery separators, pencils, etc. It is widely used for general joinery and carpentry works, ship and boat making, carriages, agricultural implements, etc.

A variety of camphor is extracted from the wood by distillation. Flowers yield an essential oil used in perfumery known commercially as Champaca oil. Champ may make good substitutes for sitka spruce for aircraft work. Leaf extract may be used as fungicide against the rice fungus, *Pyricularia oryzae*. Fatty oils extracted from the seeds show antibacterial activity against

Bacillus pumilus, *B. subtilis*, *Salmonella typhosa*, *S. paratyphi*, *Micrococcus pyogenes* var. *albus* and *Staphylococcus aureus*. Leaf, bark, root flower and fruit are of medicinal value. Flowers and barks are useful in diabetes, quick wound healing, cardiac disorders, gout, dysuria, etc. Leaves are used for rearing silkworms.

Environmental Benefit

Reclamation: The tree is used to reforest in eroded areas.

Soil improvement: Soil under tree cover shows an increase in pH, soil organic carbon and available phosphorus.

Ornamental: As a roadside tree plantation, champ may be utilized for its aesthetic value.

Way Forward

Titachapa based Agri-Silviculture or Horti-Silviculture system has tremendous scope especially in the foot hill region, flood free areas.

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