

AGROFORESTRY (Ad hoc recommendations)

Agroforestry refers to land management systems that integrate agricultural crops with forest crops. It is a collective term for all land use systems and practices in which woody perennials are deliberately grown on the same land management unit as crops or animals, either in some form of a spatial arrangement or in a time sequence and in which there is a significant interaction between the woody perennials and the crops or animals.

Types of Agroforestry

The major classes of agro forestry include, agrisilviculture, silvopastoral, agrosilvopastoral and other (miscellaneous) systems.

Agrisilviculture refers to systems in which agricultural crops are integrated with trees on the same land management unit either in time or space. Examples include taungya, alley cropping, multipurpose trees either as woodlots or as scattered trees on farmlands or on farm boundaries, crop combinations involving woody perennial plantation crops, growing commercial crops in association with planted shade trees or trees in natural forests, shelterbelts, energy plantations, enriched fallow and so on.

Silvopastoralism represents land management systems in which forests including forest plantations are managed for the concurrent production of wood and livestock. They also refer to situations in which trees are scattered in pasture/grasslands, protein banks/cut and carry fodder production system involving woody perennials and the like.

Agrosilvopastoral systems, the most intensive form of land management, are systems in which the land is managed concurrently for the production of agricultural and forest crops and for rearing of domesticated animals.

In addition, there are many agricultural practices associated with forest that strictly do not fall under the above categories. These include, collection of non-timber forest products from forests, growing trees around wetlands and other water bodies in which fish culture is practised, apiculture with trees and multipurpose woodlots etc.

Trees in Agroforestry

Many tree species (woody perennials) are encountered in agroforestry. These include common timber species such as ailanthus (matti), teak, wild jack and multipurpose tree species such as mango, jack, tamarind, erythrina, gliricidia etc. Species-specific recommendations for some important timber (softwood and hardwood) trees are given below.

AILANTHUS OR MATTI (*Ailanthus triphysa*)

Ailanthus trees flower in February-March and the fruit, a reddish brown samara, ripens in March-April, which represents the ideal time for seed collection. The seeds can be stored for only for a few months. Alternate wetting and drying improves seed germination. The procedure involves soaking the entire quantity of seeds in cold (room temperature) water in the evening and draining the water next morning, followed by drying the seeds under shade during the day. The cycle is repeated for two to three days.

Nursery practices

Raised beds of 10 x 1 m are formed. Preferably sand, soil and farmyard manure (1: 1 : 1 ratio) must form the top layer of the beds. Sowing is done after the bed is watered. Usually sowing is done by broadcast method (or dibbling) in Nov-December, for June planting and March-April,

for October-November planting. After sowing, a thin layer of soil is sprinkled on the beds to cover the seeds. The beds are also mulched with green leaves to reduce the evaporation losses and dusted with carbaryl 10% to prevent insect attack. Seed rate is 1 kg per bed. After sowing, watering is done with a fine rose-can twice a day for 10-15 days and once a day afterwards. The nursery beds also must be weeded as and when necessary.

Pricking out

Germination takes place in about 8-10 days after planting and the seedlings attain a height of 10-15 cm in six weeks time. They are then pricked out into polythene bags containing 1: 1: 1 mixture of sand, soil and FYM.

Planting practices

Containerised stock (commonly in polybags, but also in root trainers) is planted in pits (1520 cm cube) at 2 x 2 m spacing with the onset of rains, in the case of monospecific woodlots. To suit the requirements of intercropping, the row-to-row spacing can be altered.

Two to three weedings may be necessary in the initial years to keep the plantation weed -free. Fertilizers may be applied @ 30-40 g N, 15-20 g P₂O₅ and 15-20 g K₂O per year per sapling from the second year to the fifth year and thereafter once in three years for a pure plantation.

In case too many lateral branches are produced, pruning may be practised. The trees can be felled/harvested over a period of 8 to 10 years.

Pests

Nursery: The two major pests are shoot webber (*Alteva fabriciella*) and defoliator (*Eligra narcissus*). Shoot webber is economically more important because it will damage the terminal shoot and can result in epicormic branch formation. It can be controlled by application of monocrotophos, quinalphos or methyl parathion at 0.05%

Young plantations: The above two are the major pests in young plantations also, but control measures may not be cost effective. If required, 0.1% of the above insecticides can be applied using rocker sprayer. Shoot webber affects seed production. Usually control measures are not adopted but any insecticide, which is recommended under the nursery, can be used.

CASUARINA (*Casuarina equisetifolia*)

Casuarina is a large evergreen tree with a straight bole and numerous, long, slender, drooping, jointed, leafless branchlets arising from rough woody branches. The jointed branchlets, which are partly deciduous, are green and perform the functions of leaves. Leaves are minute scale like and arranged in the form of a cup at the joints of the branchlets. Bark is brown, rough, fibrous and exfoliating in longitudinal strips. Wood is very hard, but liable to crack and split. It is used as timber, poles, pulp and paper besides fuel-wood. Casuarina is grown as an ornamental tree throughout the tropical and subtropical parts of India. In addition, it can be grown in agroforestry combinations involving diverse crops. Fodder grasses, other agronomic crops such as pulses, oil seeds and vegetables, coconut palms and tree crops such as teak and ailanthus are important in this respect,

Propagation

Propagation is by seeds or through vegetative means. For seedling production, about half kg seeds are sown on raised nursery beds of 10x 1 m. This will produce about 10,000 good quality seedlings. If the soil is sandy, mix farmyard manure with the topsoil. After sowing the seeds, a

thin layer of sand is sprinkled to cover the seeds. Usually sowing is done in Nov-December. Regular watering and shading of the nursery beds are necessary to facilitate rapid seed germination. Germination takes about 10 days and seedlings attain a height of 10-15 cm in 6 weeks. They are then pricked out into polythene bags or transplanted into beds of size 1 x 10 m in January-February.

Vegetative propagation is by branch cuttings, stump cuttings and layering. For vegetative propagation by rooting of branch cuttings, treat 5-7 cm long cladode cuttings with rooting hormones. The hormone treated cladodes are transferred to presoaked vermiculite and kept in a mist chamber. About hundred per cent rooting is obtained within 15 days. The rooted cuttings are then transferred to a mixture of sand, soil and farm yard manure (2: 1: 1) for hardening. After 15 days, the hardened propagules can be transferred to the field.

Planting and stand management

Casuarina has a wide environmental adaptability and hence occupies sites ranging from arid regions to coastal zones. Being an actinorhizal plant, casuarina is capable of biological nitrogen fixation. Therefore, it thrives best on sandy soils low in nitrogen and has the potential to improve the nitrogen capital of impoverished sites.

Site preparation includes ploughing the land 2-3 times and making 30 x 30 x 30 cm pits before the onset of monsoon. The pits are filled with farm yard manure and topsoil. Planting is done immediately after the first rains. Block planting, row planting and line or strip planting are common. Spacing varies depending on the objective and the end product. Usually a spacing of 75 cm x 75 cm is adopted. One or two weeding is done immediately after the rains. When the trees are about 3 m in height, the lateral branches are pruned to a height of about 2 m. Pruning is usually done at the end of the second year or after the beginning of the third year. In plantations established at close spacing (75 x 75 cm), one thinning in the second year or third year depending on tree growth is desirable, where 25-50% of the trees are felled. In mixed species systems such as agroforestry, spacing and thinning practices are mainly dependent on the cropping systems and the nature of the associated species. If the associated crops are shade intolerant generally wider spacing and or intensive thinning are recommended. Fertilizers may be applied at the rate of 20-25 g N, 15-20 g P₂O₅ and 1520 g K₂O per seedling per year from the second year to the fifth year.

Injuries and protection

Damping off, seedling blight, stem canker and seedling rot are encountered in the nurseries. Emisan 0.01% is effective against these diseases. Stem-wilt or bark blister disease caused by *Trichosporium vesiculosum* is a serious disease in the plantations. The disease affects trees of 3-4 years and causes mortality up to 80%. Maintaining a soil pH of 6.5 to 6.8 and treating the plantation with fungicidal sprays can control this disease. Other diseases include stem canker and dieback caused by *Phomopsis casuarinae*, pink disease caused by *Corticium salmonicolor*, root rot disease caused by *Ganoderma lucidum* and heart rot caused by *Polyporus glomeratus*, *Fomes fastuosus* and *F. senex*. Stem canker and dieback can be controlled by carbendazim @ 0.01 %.

Insect pest problems to the tune of regular epidemic infestations inflicting extensive economic losses rarely occur in casuarina.

Harvest

Casuarina seedlings growing rapidly at the rate of about 1.2 to 1.5 m per annum during the initial seven to eight years are usually harvested in about 7-10 years. Yield of high density fuel-wood plantations varies from 10-20 tonnes per ha per year on 7-10 years rotations. Higher yields are reported from irrigated and fertilized sites.

EUCALYPTUS (*Eucalyptus* spp.)

Eucalyptus is an Australian genus comprising of 140 species. They are evergreen species, all more or less aromatic and containing oil glands in their leaves. Mysore gum (*Eucalyptus tereticornis*), flooded gum (*Eucalyptus grandis*), blue gum (*Eucalyptus globulus*) and lemon-scented gum (*Eucalyptus citriodora*) are the important eucalyptus species grown in Kerala. Of these, Mysore gum and flooded gum are important timber species in the low- and mid-altitudinal zones of the state, respectively. The cultivation practices of these two species are described below.

E. grandis grows best in deep, permanently moist, well-drained soils. *E. tereticornis* also prefers moist and well-drained soils such as loamy sands or alluvialloams, with high nutrient availability. A certain degree of salinity is tolerated, but strongly acid soils are ill suited. *E. tereticornis* adapts to a variety of sites, but responds poorly to excessively long dry periods. It is very easy to regenerate both species and they are good coppicers. The number of seeds per kilogram for *E. grandis* is 2.5 million, whereby roughly 630 viable seeds can be expected per gram. In the case of *E. tereticornis* one gram contains approximately 540 seeds.

Planting stock

Three-month-old containerized stock (polybag seedlings or root trainer seedlings) is recommended for planting. For seedling production, sow the seeds in seed tray in February. Trays should be kept moist with a fine spray of water until germination begins. Germination begins 7-9 days after sowing. The seedlings should be pricked out when they have two pairs of leaves into poly-bags of size 22 cm x 10 cm or root trainers. Planting stock of high yielding disease resistant clones are available at the KFRI / Kerala Forest Department nurseries.

Planting and stand management

Best time for planting is the beginning of rains. Planting is usually done in 20 cm x 20 cm x 20 cm pits (for clones use 30 cm cube pits) at 3 m x 3 m spacing. For production of pulpwood and fuel-wood, 6-10 year rotations are used without thinning. Depending on site conditions, *E. grandis* and *E. tereticornis* may respond to mineral fertilization with accelerated growth. Fertilizers may be applied at the rate of 30 g N, 30 g P₂O₅ and 15 K₂O per sapling per year during the second, third and fourth years.

Injuries and protection

Polyphagous insects seem to attack the nursery stock. Quinalphos or malathion 0.05% is recommended against them. Drenching the containers with chlorpyrifos is a preventive measure against termite attack in plantations. Quinalphos 0.2% solution is recommended to control stem borer attack.

Cylindrocladium leaf blight and pink diseases are common in eucalyptus trees. To control *Cylindrocladium* leaf blight, drench the nursery with carbendazim 0.05%. Bordeaux paste is recommended against pink disease. Using disease tolerant clones is a sure means of preventing the incidence of both diseases.

Uses

E. grandis wood is pink to pale reddish brown in colour. It has good bending properties. It is used for housing construction, floors, furniture, crates, and veneers, in the paper industry and as fuel-wood. *E. tereticornis* produces dark red wood. It is hard, strong, tough, heavy, very durable and resistant to termite attack. It is used for a wide range of construction applications,

suited for trench linings and fuel-wood.

MANGIUM (*Acacia mangium*)

Mangium is a major fast-growing tree species in forestry plantation programmes in Asia and the Pacific. It tolerates varied site conditions and has adaptability to different planting objectives. Mangium shows most vigorous growth on well-drained, fertile soils in high rainfall areas (>2000 mm annually) in the humid tropics.

Propagation

Flowering in mangium is precocious. It starts to flower and produces seeds 18-20 months after planting. Pods can be collected from the trees in January-February under Kerala conditions, when the pods turn very dark-green to light-brown in colour. Seeds are extracted manually after suodrying. Pods and seeds should not be left to dry in the sun for long. Store the seeds under dry and insect/rodent-free conditions. The number of seeds in one kg of pure seed varies among trees (mean: 125,000 seeds per kg).

Pre-sowing treatment and nursery practices

To break dormancy of mangium seeds, hot water treatment is recommended. Pour the seeds into water at 100°C that is removed from the heat source. Stir the seeds for exactly 30 seconds. Pour off the water. Add cold water (room temperature) 20 times of the seed volume. Let stand overnight to imbibe and sow the seeds in the nursery beds/seed trays. Seed inoculation with appropriate rhizobial strain is recommended before sowing. Mangium seedlings are ready for pricking out in 6-10 days after sowing. Polythene bags are the most common containers used in the tropics for pricking out. Mangium seedlings attain a target size of 25-40 cm height in about 12 weeks. Seedlings are hardened by progressively reducing watering and removing shade in the nursery. If the seedlings have grown larger than the target size in the nursery, they may be lopped.

Planting and stand management

Planting is usually done in pits of 20 cm depth and 10-12 cm diameter. In monospecific stands, spacing of 2 x 2 m or 2.5 x 2.5 m is common. However, if saw log production (large diameter stems) is the objective, wider spacing (3-3.5 m between rows and between plants) should be followed. In agroforestry situations, spacing within rows and between rows must consider the effect of shade and root competition on the yield of associated crops.

First weeding must be carried out two months after planting and thereafter at regular intervals depending on weed growth. On favourable sites, mangium plants emerge and dominate the weeds within two years, thus not requiring any further weed control. Fertilizers may be applied @ 30-40 g N, 15-20 g P₂O₅ and K₂O per seedling per year from the second year to the fifth year. Mangium needs regular pruning and thinning if the plantation objective is to produce quality saw logs on a 15 to 20 year rotation. These operations in general are not required for pulp wood production on a 6 to 8 years rotation. However, multi-stemmed seedlings may be 'singled'. In pruning, branches are carefully removed in one or more steps along the bottom trunk up to about 6-7 m height. For saw log production regimes the following silvicultural schedule is recommended.

Table 26. Silvicultural management schedule for mangium saw log regime

Age	Activity	Remarks
		Uproot all climbers within 45 cm radius

4 months after planting	General slashing	of each plant. Remove branches at height less than 30 cm from the ground.
6 months after planting	General slashing	As above
12 months after planting	General slashing and first pruning	Remove all branches up to 1.5-2.0 m height.
2 years after planting	First thinning and high pruning	Remove 300 trees/ha, retaining 600 trees/ha. Prune branches up to 6 m height of the 200 selected trees (to be retained till end).
4-5 years after planting	Second thinning	Remove another 200 trees/ha retaining 400 trees/ha.
8-9 years after planting	Final thinning	Remove another 200 trees/ha.

Injuries and protection

Although root rot disease caused by *Ganoderma* sp. (red rot), *Phellinus* sp. (brown rot) and *Rigidoporus lignosus* are major problems in mangium stands, there are no specific control recommendations against these fungi. Signs of the disease are evident on the roots after the tree has fallen or upon excavation. Depending on, which fungus causes the disease, there may be dark reddish granular rusty brown encrustation or white thread-like rhizomorphs on the surface of the roots. The usual method of controlling root rot caused by fungi that spread by root contact is to remove and destroy all diseased roots and woody debris.

Chemical protection against pink disease (*Corticium salmonicolor*), especially in endemic areas, can be achieved by using copper fungicides. The best way to prevent pink disease, however, is to plant tolerant varieties.

Progressive decay of the heartwood (heart rot) is another malady afflicting mangium trees. Normally, fungi that decay heartwood do not attack sapwood; such trees continue to grow to maturity and may outwardly appear healthy and vigorous. However, since heart rot is progressive, there will be considerable decay cull at the end of the rotation. A variety of basidiomycete fungi have been associated with this malady. At present there are no control measures against mangium heart rot. The best way is to avoid injury to trees and wound dressing.

Although about 30 insect species are reported to be pests of mangium, only a few such as root feeders, branch and stem borers and the red coffee borer are considered economically important. Root feeders (*Sternocera aequisignata*) can be controlled by, carbofuran and chlorpyrifos application to the soil or seedbeds. For controlling termites apply a water solution of chlordane 1 % or dieldrin 0.5% around the affected area. To prevent branch and twig borer (*Sinoxylon anGLE*) occurrence, remove and burn all broken branches in which breeding takes place. The only effective method to control red coffee borer (*Zeuzera coffeae*) damage is to inject insecticide into the holes where larvae push out their frass.

Utilization of mangium wood

Timber is used for a variety of purposes like wood-based panels, pulp and paper Industry etc. Mangium wood gives attractive furniture, cabinets, moulds and door/window components. However, the presence of flutes and incidence of rots and termite attack will detract both the quality and quantity of sawn timber from mangium logs. Therefore, mangium has greater potential as a component of composite wood products such as veneer and plywood, laminated veneer lumber, fibreboards etc. and for chemical uses such as pulp, paper and tannin production, besides fuel-wood.

TEAK (*Tectona grandis*)

Teak is the paragon among Indian timbers. It is a large tree that attains a height more than 30 m. Teakwood is extensively used in construction, for making door/window shutters and frames, furniture, cabinets, railway coaches and wagons, and ship/boat building. It is an ideal wood for parquet and decorative flooring and excellent wood for wall panelling. The species is indigenous to India and the Southeast Asian region. In India teak is distributed naturally in the peninsular region. It prefers a warm moist tropical climate with mean annual precipitation of 1100-2000 mm and a well-drained fertile soil. Being a strong light demander it does not tolerate overcrowding and does not withstand waterlogging.

Propagation

Seeds (fallen fruits) should be collected from vigorously growing middle-aged trees characterized by straight boles, desirable branching habit, good form and less fluting. Freshly fallen intact fruits with inflated calyx from such trees can be collected during December-February. The ground must be cleared before hand by removing litter and other materials to facilitate seed collection. After cleaning and drying the seeds may be safely stored in gunny bags or sealed containers. Seeds of diameter greater than 9 mm are usually collected. For convenience in storage and transport, the bladder like calyx of the fruit is removed. This is done by half-filling a bag with the fruits and vigorously rubbing and shaking it or by beating with sticks, after which the remains of the calyces are separated from the nuts by winnowing. Due to hard seed coat, germination of one-year old seeds is better than that of fresh seeds.

Pre-sowing seed treatment

1. Wetting during night followed by drying in the sun. Repeat for two to three weeks.
2. Termite feeding: Spread the teak fruits on the ground in a 5 cm layer immediately after collection. After about five weeks the termites remove the exocarp and subsequent germination after alternate wetting and drying is found to be better.

Nursery practices

Raised beds (30 cm high, supported with split areca stems) of 10 x 1 m are formed. Sand and soil mixed with farmyard manure form the top layer. Sowing is done after the bed is watered. Usually the sowing is done by broadcast method or dibbling in April-May. Seed rate is 3-5 kg of seeds per bed. After sowing, the seeds may be pressed into the beds. A thin layer of soil also can be sprinkled to cover the seeds. The beds are also mulched with green leaves to reduce evaporation losses. The bed is then dusted with carbaryl 10% to prevent insect attack.

One-year-old seedlings of 1-2 cm (thumb thickness) at the thickest portion below the collar are removed from mother beds and used for making stumps. Stumps with 15-20 cm of root at 2-3 cm of stem prepared with sharp knives are commonly used for planting. Teak seedlings can be produced in shorter duration by using polythene bags or root trainers. Three to four month old teak seedlings are pricked *out* from the germination beds into polythene bags (30 cm x 20 cm) in the month of March- April. Three month-old root trainer seedlings are also popular, of late.

Planting

With the pre-monsoon showers, stump planting is done in crowbar holes during April-May (four to six weeks before the onset of regular monsoons). The site must be cleared of stubble or other competing vegetation, if any. If containerized planting stock (polybags, root trainer) is used, then optimal time of planting may be after the onset of southwest monsoon in June-July. They are usually planted in pits of size 30 cm x 30 cm x 30 cm. Spacing recommended for monospecific woodlot is 2 m x 2 m. However, if intercrops are proposed to be raised, then row-to-row distance can be altered. For one or two row strip plantings at farm boundaries, a closer plant-to-plant spacing of 1 m could be employed.

Weeding and fertilization

Six or seven weeding may be necessary during the first two years. Teak is very susceptible to weed competition. Fertilizers may be applied @ 30-40 g N, 15-20 g P₂O₅ and 15-20 g K₂O per plant per year from the second year to the fifth year and thereafter once in three to four years for 10-12 years. In agroforestry situations, if the intercrops are fertilized, the quantities of chemical fertilizers applied to teak can be proportionately reduced or even skipped. Providing life-saving irrigation during the summer season favours teak growth.

Thinning.

For a fifty-year rotation, monospecific teak plantation on a good site (initial spacing 2 m x 2 m), thinning may be carried out at 4, 8, 12, 18, 26 and 36 years after planting. Thinning in short rotation (25-30 years) high input plantations can be at 4, 8, 12 and 16 years. The thumb rule governing thinning is that trees should not be allowed to compete with each other for site resources, as intense competition may depress teak growth. Therefore, considering the site characteristics, tree growth rate and merchantability of the thinned out materials, a flexible thinning schedule can be adopted. A teak density management diagram can be used for this purpose. In general thinning is delayed on poor sites.

Mixed plantations

Fruit/spice/medicinal trees can be successfully intercropped with teak throughout its growth. Additionally, inclusion of nitrogen fixing trees such as *Gliricidia* or *Leucaena* (subabul) either in alternate rows or every third row not only improves teak growth but also saves chemical nitrogenous fertilizers. However, manage (by lopping or pruning) the nitrogen fixing tree component in such a way that it does not compete with teak for light.

Pests, diseases and their control

White grubs feed on roots in the nursery. Apply phorate IOG or carbofuran 3G @ two teaspoon full mixed with fine sand. Vascular wilt disease (*Burkholderia solanacearum*) is noticed in nursery and young plantations. As preventive measures against this disease, maintain proper drainage and avoid root injury. Leaf spot disease (*Phomopsis* sp. and *Colletotrichum gloeosporioides*) in nursery and young plantations can be controlled by mancozeb 0.05% or carbendazim 0.05% application. Against pink disease (*Corticium salmonicolor*) in young plants, apply Bordeaux paste.

Defoliators (*Hyblaea parea*) and skeletonisers (*Eutectona machaeralis*) can be controlled by quinalphos 25 EC 0.05% spray.

However, only in small plantations / woodlots chemical control through insecticide spray is advocated. For controlling stem borer (*Sahyadrassus malabaricus*) apply 0.2% quinalphos at

the site of infection after removing the frass. A void injury to root and collar to prevent bud rot and heart rot occurrence. Cut and remove the parasitic plants (*Dendrophthoe falcata* var. *pubescens*) before fruiting.

THORNY BAMBOO (*Bambusa arundinacea*)

Bamboos are woody perennial grasses that occur in the tropical and subtropical evergreen and deciduous forest formations of Asia-Pacific. Important uses of bamboo include paper and pulp industry, fuel, food, feed, house construction, and scaffolding, making several articles of everyday use, besides controlling soil erosion. One hundred and thirty wild and cultivated bamboo species are reported to occur in India. They exist under diverse ecological conditions, often as an under-storey in many forest types. In agroforestry, thorny bamboo is perhaps the most important species in Kerala.

Propagation

Bamboos are propagated either by seeds or vegetative means (offsets, division, culm/ rhizome cuttings or layering). In general, bamboos are monocarpic, ie. They flower only once and die after producing seeds: Most of the economically important bamboos flower gregariously at long intervals of 30-40 years. Although large quantities of seeds are produced during gregarious flowering, they are viable only for about six to eight months. Seeds can be germinated in nursery beds and pricked out into polybags of size 18 cm (flat width) x 22 cm. One year-old seedling can be used for planting. However, when seeds are not available, bamboos are propagated vegetatively.

Propagation by offsets is the common method of vegetative propagation. One-year old culms in a clump are given a slanting cut at about 90 to 120 cm above the ground. The rhizomes to which they are attached are dug out with the roots intact. The shoot portion is then cut off to a length sufficient to include a well-developed bud. These offsets are planted out sufficiently deep in the soil to cover the first two or three nodes. Planting should be carried out immediately before the rainy season. During extraction care must be taken to avoid damage to roots and rhizomes of mother clumps.

Work at the KFRI has shown that using rooted culm cuttings is a viable alternative to the laborious offset method. For vegetative propagation using culm cuttings, extract 2 to 3 year old culms from healthy clumps by cuttings just above the first node during March-April. Trim the leaves and side branches without injuring the axillary buds. Prepare two-node cuttings (leaving about 5-7 cm on either side of the nodes) using a sharp knife or saw. Make a small slit (about 2 m long and 1 cm wide) or drill holes (about 7 mm diameter) in the middle of the inter node. Wrapping in moist gunny bag or embedding in boxes containing moist saw dust might minimize exposure of the cuttings. Pour about 200 ml of NAA (1-naphthalene acetic acid) solution (100 ppm) carefully into the culm cavity through the slit and close the slit/hole by wrapping with a polythene strip. Ensure that the polythene wrapping is tight so that the solution does not leak out. After extraction, the culm cuttings should be treated with NAA as quickly as possible.

Prepare raised nursery beds of 10m x 10m and fill with a mixture of soil and sand (3: 1). One week prior to planting, drench the nursery bed with 40 litres of aldrin 0.015% and 30 litres of carbendazim 0.05% to prevent termite and fungal attacks. Place the cutting horizontally (the opening facing upwards) across the nursery bed. About 50-60 cuttings may be conveniently planted in a raised nursery bed. Cover the cuttings with a thin layer of soil. Provide shade and water the beds regularly till the onset of monsoons but avoid waterlogging. Rooted cuttings can be transplanted to the field in about four months. Cuttings sprouted and rooted at both the nodes of a culm cutting must be separated carefully through the middle to get two plants.

Propagation by division is usually done in the case of dwarf bamboos, which are easy to handle. It involves splitting / dividing the mass of rhizomes and planting out the culms in small clumps with two or three culms attached. Other methods of vegetative propagation include rhizome cuttings and air layers. Sections of fresh living rhizome of the preceding year about 15 to 30 cm long containing at least one bud and air layers form successful means of propagating some bamboo species.

Planting and fertilization

Spacing recommended for mono-specific bamboo plantations is 10 x 10m. Propagules can be planted in pits of size 45 cm x 45 cm x 45 cm. Fertilizers may be applied at the rate of 40 g N, 10 g P₂O₅ and 75 g K₂O per plant per year in 1-2 year old plantations.

Competitive interactions based agroforestry in bamboo

Being perennial grasses, bamboos have higher root length densities than dicots. Thus in mixed species system, bamboos may out-compete the field crops or other tree crops grown in association. However, interspecific competition in bamboo-based agroforestry systems can be overcome by planting crop 8-9 m away from the bamboo clumps. Trenching (30-40 cm wide and 50-60 cm deep at 5-6 m away from the clumps) to spatially isolate bamboo roots from the rest of the crops is recommended, if crops are to be planted at shorter distances. Bamboo root competitiveness is usually a function of its rooting intensity with crown radius. Larger clumps have wider foraging zones usually extending to about 8 to 9 m. Therefore canopy reduction treatments such as pruning and culm thinning are appropriate to surmount interspecific competition. Pruning up to a height of 1.5 above the ground is recommended in plantations of four year and above. Also remove the dry and dead culms from the centre of the clump to reduce congestion.

Pests and diseases

The bamboo plantations in Kerala do not face any serious insect problems. Young plants, however, are likely to be affected by shoot borers and sap suckers. In bamboo nurseries, damping off caused by *Rhizoctonia solani* is a major disease. It can be controlled by prophylactic fungicidal treatment and by regulation of shade and watering. In young plantations, rhizome bud rot (*Pythium* sp., *Fusarium* sp.), rhizome decay (*Pseudomonas* sp.) and basal culm decay (*Fusarium* sp.) are important.

Extraction of bamboo culms

Either all the old culms, i.e. those more than three years old (six years in the case of clumps regenerated from seedling) or a certain number of mature culms are removed annually. Older culms in the interior of the clumps should be removed in a horseshoe pattern. The height of cuttings is usually at 30-50 cm above ground. It is necessary that cuttings should leave at least one node above the ground to prevent rainwater soaking into the rhizome.

WILD JACK OR AINI (*Artocarpus hirsutus*)

Ideally suited for boundary planting and for as scattered trees on the fann field.

Performance under monocultural situations is not promising. Seeds or wildings (scattered seedlings found profusely on the fann fields) can be collected during the monsoon season and planted at the desired spots in the field. On fann boundaries, closer plant-to-plant spacing (1 m) can be adopted.

AGROFORESTRYSYSTEM

Agrisilvicultural systems

Shade loving crops such as ginger perform better in the inter-spaces of tree species such as ailanthus (at four years of age, planted at a spacing of 2 x 2 m; with 60% of the light in the open).

Multipurpose tree species like ailanthus, teak, vellapine, silver oak and green manure yielding trees can be successfully interplanted in the older coconut plantation (preferably above 30 years of age), often in association with other field crops including medicinal plants such as kacholam. Depending on the space available (between coconut palms), one or two rows of multipurpose trees can be accommodated in the middle (spacing 1-2 m between plants). Tree management such as lopping or pollarding etc. is important to prevent any possible interspecific competition between the multi-purpose tree component and the coconut palms.