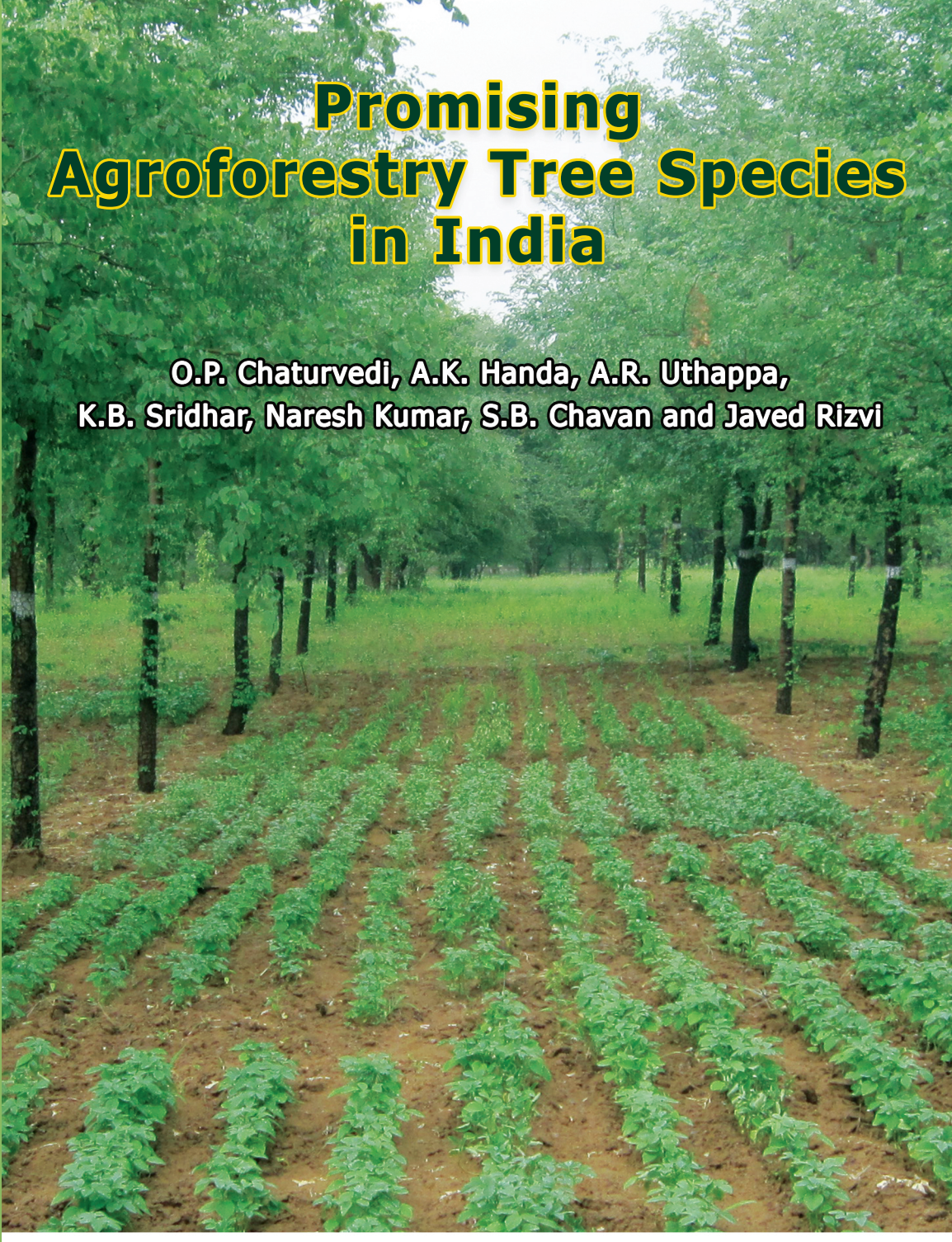
Promising Agroforestry Tree Species in India

O.P. Chaturvedi, A.K. Handa, A.R. Uthappa,
K.B. Sridhar, Naresh Kumar, S.B. Chavan and Javed Rizvi



भाकृअनुप
ICAR

World Agroforestry Centre

केंद्रवाअनुसं
CAFRI

CAFRI

Mission

The mission of the **Central Agroforestry Research Institute (CAFRI)**, one of the national institutes under the umbrella of the Indian Council of Agricultural Research (ICAR) is: To improve quality of life of rural people through integration of perennials on agriculture landscape for economic, environmental and social benefits.

ICAR

Mission

The mission of the **Indian Council of Agricultural Research (ICAR)** is: To harness the power of science and innovation for food security, food safety, farmer prosperity and enhance the natural resources base to promote inclusive growth and sustainable development.

ICRAF

The **World Agroforestry Centre (ICRAF)** is a centre of scientific excellence that harnesses the benefits of trees for people and the environment. Leveraging the world's largest repository of agroforestry science and information, we develop knowledge practices, from farmers' fields to the global sphere, to ensure food security and environmental sustainability. ICRAF is the only institution that does globally significant agroforestry research in and for all of the developing tropics. Knowledge produced by ICRAF enables governments, development agencies and farmers to utilize the power of trees to make farming and livelihoods more environmentally, socially and economically sustainable at scales.

ICRAF is one of the 15 Centers of the **CGIAR (Consultative Group on International Agricultural Research) Consortium**. ICRAF's headquarters are based in Nairobi, Kenya, with six regional and sub-regional offices located across Africa, Asia, and Latin America.

CGIAR

The **CGIAR Consortium** integrates and coordinates the research of its 15 member-Centers to increase the effectiveness and relevance of their work, and enhance the impact of the research by setting common objectives and planning concerted action.

Promising Agroforestry Tree Species in India

O.P. Chaturvedi, A.K. Handa, A.R. Uthappa, K.B. Sridhar, Naresh Kumar, S.B. Chavan and Javed Rizvi

Jointly published by
Central Agroforestry Research Institute (CAFRI)
South Asia Regional Programme of the World Agroforestry Research Centre (ICRAF)

Recommended citation:

Chaturvedi, O.P., Handa, A.K., Uthappa, A.R., Sridhar, K.B., Kumar, Naresh., Chavan, S.B. and Rizvi, Javed. 2017. Promising Agroforestry Tree Species in India. Jointly published by the Central Agroforestry Research Institute (CAFRI), Jhansi, and the South Asia Regional Programme (based in Delhi, India) of the World Agroforestry Centre.

About the authors:

Dr O.P. Chaturvedi is Director; Dr A.K. Handa is Principal Scientist; A.R. Uthappa and Dr K.B. Sridhar are Scientists; Dr Naresh Kumar is Senior Scientist; and S. B. Chavan is Scientist, at the Central Agroforestry Research Institute (CAFRI), Jhansi, U.P., India.
Email: director.cafri@gmail.com

Dr Javed Rizvi is Director of the South Asia Regional Programme, based in New Delhi, India, of the World Agroforestry Centre (ICRAF), based in Nairobi, Kenya. Email: j.rizvi@cgiar.org

Address of publishers:

Central Agroforestry Research Institute (CAFRI), NH- 75, Rasra, Jhansi, Uttar Pradesh 284003, India. www.cafri.res.in

South Asia Regional Programme, World Agroforestry Centre (ICRAF), 1st Floor, Block C, National Agricultural Science Complex (NASC), Dev Prakash Shastri Marg, Pusa Campus, New Delhi 110012, India.
www.worldagroforestry.org

Contents

Foreword

Agroforestry has traditionally been a way of life and livelihood in India for centuries. The role of agroforestry in improving land productivity, soil conservation, bio-amelioration, climate moderation, and increasing farmers' income is widely acclaimed today.

Research and development activities in agroforestry gained momentum in India since 1983 with the launch of the All India Coordinated Research Project (AICRP) on Agroforestry by the Indian Council of Agricultural Research (ICAR). Generation of knowledge on tree-based farming systems through this AICRP led to the establishment of a National Research Centre on Agroforestry (NRCAF) in 1988 in Jhansi, U.P., which was renamed as Central Agroforestry Research Institute (CAFRI) in 2014. These initiatives got a further boost when ICRAF (World Agroforestry Centre) joined India's agroforestry programme in 2003. Partnership with ICRAF gave India access to international expertise and advanced tools and techniques of research.

Recognizing the potential of agroforestry as a pro-poor, multi-benefit land management system, the Government of India launched the National Agroforestry Policy in 2014. The Policy enables institutional arrangements at national level to promote agroforestry under the Ministry of Agriculture and Farmers Welfare; simplify regulations related to harvesting, felling and transportation of trees grown on farmlands; ensuring security of land tenure and creating a sound base of land records and data for developing a Market Information System for agroforestry; access to quality planting material; institutional credit and insurance cover to agroforestry practitioners; and increased participation of industries using the agroforestry products.

With multiple research initiatives underway, a lot of scientific knowledge on different aspects of agroforestry has been generated. This book "Promising Agroforestry Tree Species in India", jointly produced by ICAR-CAFRI and ICRAF, taking field experiences out of AICRP on Agroforestry to different climatic conditions, is an assemblage of meaningful knowledge in this sector.

I hope this publication will be useful for practitioners, planners, forest officials, farmers, and teachers and students of agroforestry.

T. Mohapatra
Secretary,
Department of Agricultural Research and Education &
Director General, ICAR, Government of India

9 November 2017
New Delhi

Preface

Agroforestry or growing trees in combination with agricultural crops is an age-old practice, especially in Asia and Africa.

India, today, stands at the forefront of global efforts in promoting research and education in agroforestry. Agroforestry systems, in addition to the economic and other benefits, also provide environmental services leading to resilience of agriculture through adaptation to, and mitigation of, climate change. Being perennials, the trees provide an element of long-term economic stability to the farmer in the event of a crop failure. This is more true for Indian agriculture where more than 60% of the net sown area is rainfed.

The Fourth Quinquennial Review Team (QRT) constituted by the ICAR to review the progress of CAFRI and AICRP on Agroforestry identified 20 important agroforestry tree species and recommended to have uniform harvesting and transit rules across the country for the promotion of agroforestry on one hand and to provide sufficient raw material to wood-based industries on the other. The National Agroforestry Policy adopted by India also identified these important multipurpose tree species to be promoted under agroforestry. In this publication, in addition to those 20 species, we have identified five more important agroforestry tree species based on their usefulness as multipurpose trees that provide timber, fuel, fodder, fruits, biofuels, raw materials for industry, chemicals for medicinal use, and more.

Given that research in agroforestry has been moving at a fast pace in India in recent years, a huge body of scientific knowledge has become available. We felt there was a need to consolidate this research-based knowledge about each tree species, selected by us, at one place in this book. While the species covered here are arranged

in an alphabetical order, each one of them is given a Chapter number for ease of reference. And, for each species, the coverage goes from its botanical characters to how it can be propagated to its suitability for the different agroforestry systems in different climatic zones. Information about cultural operations for each species is also included.

This book is an example of the new knowledge and products emerging from the collaboration between ICAR-CAFRI and ICRAF. We hope the book will prove useful for farmers, in the first place, in selecting the most appropriate tree species to grow on their farms, and how to nurse them, in various agro-ecological zones of India; as well as to other user groups, including students, teachers, researchers, policy makers and the general public.

In working on this book, we had to refer to multiple research articles and reports published in literature by our fellow researchers. While every effort was made to cite the sources of the information, we may have inadvertently missed some. We would greatly appreciate the readers' understanding in this regard.

We would like to acknowledge the valuable support (including the images used in this book) from the scientists of the All India Coordinated Research Project on Agroforestry (AICRP on AF), ICAR- CAFRI, Jhansi and ICRAF-Delhi in producing this book.

O.P. Chaturvedi
A.K. Handa
A.R. Uthappa
K.B. Sridhar
Naresh Kumar
S.B. Chavan
Javed Rizvi

13 November 2017

Chapter 1

Acacia mangium Wild

Family: Fabaceae
Common name: Black wattle, brown salwood, hickory wattle, mangium
Trade name: Brown salwood
Origin: Australia, Indonesia, Papua New Guinea

Botanical Characters

Acacia mangium, also known as mangium, is one of the most widely used fast-growing tree species in plantation forestry programmes throughout Asia and the Pacific. It is a single-stemmed evergreen tree or shrub that grows to 25-35 m in height. Young trees have smooth, greenish bark; fissures begin to develop at 2-3 years. Bark in older trees is rough, hard, fissured near the base, greyish-brown to dark brown; the inner bark is pale brown. Bole in older trees is branchless for up to 15 m, fluted, and up to 90 cm in diameter; branchlets are acutely triangular. Phyllodes are large, up to 25 cm long and 3.5-10 cm broad. An extrafloral nectary gland lies at the base of the phyllode. Inflorescence is composed of many tiny white or cream flowers in spikes. Flowers are quinqeufloral; the calyx is 0.6-0.8 mm long, with obtuse lobes; corolla 1.2-1.5 mm long. Pods are broad, linear and irregularly coiled when

Pods and seeds of *Acacia mangium*

ripe. They are membranous or slightly woody, inconspicuously veined. 3-5 mm wide and 7-10 cm long. Ripening pods change from green to brown, stiff and dry. Seeds are black and shiny with shape ranging from longitudinal, elliptical, ovate to oblong, 3-5 mm by 2-3 mm. The seeds are arranged longitudinally and attached to the pods by an orange to red folded funicle (Orwa et al. 2009).

Distribution

A. mangium originates from the humid tropical forests of north-eastern Australia, Papua New Guinea and the Molucca Islands of eastern Indonesia (National Research Council, 1983). Since its successful introduction into Sabah, Malaysia, in the mid-1960s, it has been widely grown in Bangladesh, China, India, Indonesia, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand and Vietnam. The mean altitudinal range is from just above sea level to about 100 m, with an upper limit of 780 m. Distribution is strongly influenced by rainfall patterns and soil drainage.

Silvicultural Requirements

A. mangium is a species of the humid, tropical lowland climatic zone characterized by a short winter, dry season, and high total annual rainfall. It prefers wet sites with an annual rainfall of 1,000-4,500 mm. Prolonged dry periods will slow down the tree growth (National Research Council, 1983). While the annual rainfall of over 2500 mm is considered adequate for *A. mangium,* its growth is still affected by seasonal conditions (Pinyopusarerk et al. 1993). It is typically a low-elevation species associated chiefly with rainforest margins and disturbed sites on well-drained acid soils (pH 4.5-6.5) of low fertility. It also occurs behind mangroves in seasonal swamps, along streams and on well-drained flats, low ridges and mountain foothills (Pinyopusarerk et al. 1993). It grows rapidly on degraded sites with low levels of soil nutrients, and even on acidic soils (National Research Council, 1983). It performs well on lateritic soils, i.e. soils with high amounts of iron and aluminium oxide (Otsamo, 2002). However, it is intolerant of saline conditions and shade. In shade,

A. mangium grows to be stunted and spindly (National Research Council, 1983). The species can naturally regenerate in disturbed sites.

Phenology

Flowering in Acacias is precocious. *A. mangium* starts to flower and produce seeds 18-20 months after planting (Mergen et al. 1983). Mature fruits occur 3-4 months after flowering. The time from the onset of flower buds to pod maturity is about 199 days (Zakaria, 1993). Flowering phenology differs in natural and planted habitats. In natural habitat, in Australia, for example, flowers appear during February to May and the seed matures in October-December. As an exotic, the normal flowering cycle may be disrupted and flowering can occur throughout the year. In India, *A. mangium* tree flowers in June-July and seed sets in January-February. The tree is a hermaphrodite and generally outcrosses, with a tendency towards selfing. Pollinators are generally insects, *Trigona* spp. and *Apis* spp. being the active pollen vectors.

Propagation Technology

Through Seeds

Seeds can be produced from 18- to 20-month-old trees, but flowering and fruiting seasons are quite different based on locations. Seeds can be extracted manually after sun-drying the pods for several days (24-48 hours) until they turn brown/black and split. The drying temperature should remain below 43°C to avoid loss of seed viability (Krisnawati et al. 2011). Seed moisture content should be reduced below 13% to prevent fungus development. The hard impermeable seed coat confers *A. mangium* seed long viability under almost any conditions if seeds are kept dry and free from insect pests. FAO (1987) recommended storing *A. mangium* seeds in sealed, air-tight containers in a refrigerator at 0-5°C, although seed stored at ambient temperatures will retain its viability for up to 2 years.

Pre-germination treatments should be carried out to promote

uniform and high levels of germination. Before planting, seeds should be placed in boiling water for 30 seconds and then cooled by soaking in cold water for 2 hours; alternatively, they can be manually scarified. Germination is reported to be 60–80% (after pre-germination treatments). Adjers and Srivastava (1993) gave a detailed description of nursery techniques. The optimum seedling container size for best results is 300 cc. For substratum in container use either top soil mixed with compost or a mixture of tropical peat or rice husk (between 70:30 and 90:10, depending on the characteristic of peat). The optimum height of seedlings for out-planting is 25-40 cm which can be achieved in 12 weeks with proper fertilizer applications. After 3-4 weeks of proper hardening, the seedlings will be ready for planting.

Vegetative Propagation

A. mangium stem cuttings can be easily rooted if cutting materials from 6 to 12 month-old seedlings are used. Rooting percentage is drastically low with older planting stocks. At six-month age of stock plant, rooting percentage was 71% and at 24 months it reduced to 15% (Darus, 1993). High air humidity (70-90%) and fairly constant temperature (28^{o}C) is required in the rooting chamber. Use of cuttings with one phyllode and applications of auxins (500-1,000 ppm IBA) improved rooting. Rooting medium with high pH (5.8-neutral) and high water holding capacity increased rooting (Darus, 1993). Micro propagation technique for *A. mangium* has also been successfully developed and reported. For optimum induction of multiple shoots, Murashige and Skoog basal medium supplemented with 0.5 mg/l of BAP was found to be most suitable (Darus, 1993).

Cultural Operations

The site preparation depends on past and present vegetation at planting site, climate, topography, soil type, soil fertility, equipment and labour availability. When the logged over forest is to be converted to plantations, clear felling followed by burning is recommended. Disc ploughing and harrowing can also be done in grasslands (Srivastava, 1993).

Planting

Seedlings are planted manually during the rainy season on freshly prepared sites in contour lines on slopes and in straight lines on flat areas. Spacing in plantations depends on the intended uses and soil fertility. Spacing of 3 m x 3 m is common for *A. mangium*. It can also be reduced to 2 m x 2 m or 2.5 m x 2.5 m. For pulpwood and fuelwood production where form is not important, seedlings should be planted at wider spacing to produce multi-leaders and heavier branches, which may result in higher volume (Srivastava, 1993).

On most sites, *A. mangium* trees have shown little response to fertilizer and the fields are usually not fertilized (National Research Council, 1983). However, 100 g of rock phosphate is usually placed in the hole at the time of planting. It has been reported that application of suitable fertilizers in adequate amounts (e.g. 100 kg/ha N, 50 kg/ha P and 50 kg/ha K) has great potential to increase early growth of *A. mangium*.

Tending Operations

Weeding in *A. mangium* plantations is recommended to remove climbers, creepers and vines, but less harmful weeds can be left in the field to maintain lateral competition. The first weeding should be done 2 months after planting out. The number of follow-up weedings will vary for each site. In areas where Imperata grass has a stronghold, weeding should be done frequently; for example, the area surrounding each seedling is often cleared at 1.5, 3 and 5 months, and weeds between rows are slashed at the third month (National Research Council, 1983).

A.mangium seedlings grown in fairly open conditions and on good sites often develop multiple leaders. In addition, the species has a poor self-pruning ability. Therefore, singling and pruning are necessary in an early stage of stand development if the aim is to maintain full growth potential and produce good-quality timber (Mead and Speechly, 1991). Singling usually starts at 4–6 months after planting before the trees form heartwood. Pruning begins after the first year of establishment (Srivastava, 1993). The branches should be pruned before reaching 2 cm in diameter

to avoid fungal infections, especially heart rot (Srivastava, 1993). In agroforestry systems, branches are usually pruned regularly to prevent competition with agricultural crops.

Thinning is necessary only when the trees are grown to produce sawn timber and veneers. If pulpwood production is the sole objective, there is no restriction on product size and thinning is not necessary. Thinning schedule depends on initial spacing, growth rate and end use. Optimal single thinning regimes involve removal of 30–60% of stems, and optimal multiple thinning regimes always remove 50% of the stems. Optimal intensity of thinning is heavier in stands of higher density. For high-density stands, 60% thinning is generally optimal, whereas for medium-density stands optimal thinning intensity is about 40–50% (Krisnawati, 2007).

Tree Protection

Major Pests and their Control

Hutacharern (1993) has described 30 insect species attacking *A. mangium*. Important insect pests are root feeders (*Stenocera aequisignata* and termite), branch and stem borers (*Synoxylon* spp.), and the red coffee borer (*Zeuzera coffeae*). These can cause death, deformity, or reduced biomass production of *A. mangium*, and must be carefully monitored and preventive measures employed (Hutacharern, 1993). As a preventive control measure for *Stenocera* sp., isobenzan (Telodrin) can be applied. Further application of the chemical around the collar of each plant for two consecutive years after planting in March is required in areas with dense *Sternocera* sp. populations. For controlling red coffee borer, insecticides can be injected into the holes where larvae push out their frass. To save the trees, this direct injection must be done at the earliest detection of insects (Hutacharern, 1993). The adults of branch and stem borers (*Synoxylon* spp.) attack shoots and young stems. To control these insects, the infected branches should be removed and burned.

Major Diseases and their Control

The common diseases in nursery seedlings are damping off, powdery mildew, stem galls, dieback, leaf spots, charcoal root rot disease

and root knot. All these are mostly common diseases of many tree species and can be controlled by conventional nursery management techniques and prophylactic fungicidal sprays. Important tree diseases in plantations are root rots, heart rot, pink disease, dieback and stem canker. Root rots are caused by many fungal species such as *Ganoderma* spp., *Phellenus* spp. and *Rigidoporus lignosus*. There are no specific control measures for these diseases. Only dead and diseased trees can be destroyed to avoid spread of the disease. The heart rot is only evident upon felling of trees because diseased trees outwardly appear healthy and vigorous. The dieback is caused probably because of a combination of several factors like prolonged drought period and fungal infections. Cankers associated with decayed branch stubs and pruning wounds are good indicators of heart rot. Infected trees can continue to grow vigorously to maturity. Management options include adopting silvicultural practices that limit wounds to the stem, including early singling of multi-stemmed trees, short rotations and selecting provenances for slender branches and single stems.

Yield

The common rotation age for *A. mangium* plantations for pulpwood production is 6–8 years and that for sawn timber, 15–20 years. In humid regions, the productivity ranged from 35 to 45 cu m/ha/year, particularly in the southern zone of Kerala, India. On the other hand, in sub-humid climatic condition with red loamy soils as observed in some belts of northern zone, the productivity ranged from 20 to 25 cu m/ha/year.

Plantation of *Acacia mangium* in Kerala

Utilization

A. mangium wood is diffuse and porous. Its sapwood is narrow and light coloured. Its heartwood is medium-brown, hard, strong and durable in well-ventilated situations, although not in ground contact (National Research Council, 1983). The grain is straight to shallowly interlocked; the texture is fine to medium and even. The wood density ranges from 450 to 690 kg/cu m at 15% moisture content. The specific gravity of *A. mangium* grown in timber plantations is commonly between 0.40 and 0.45, whereas in natural stands it is about 0.60 (National Research Council, 1983).

The species is classified as one with medium strength properties. Its bending strength is 83.5 N/mm^2, crushing strength is 37.0 N/mm^2 and modulus of elasticity (MOE) is 10.6 kN/mm^2. The wood is reported to be moderately strong with an average bending strength value of 65 N/mm^2 in green condition.

A. mangium is an important source of wattle timber; the wood is used for construction, boat building, furniture and cabinet making, and veneer. It makes attractive furniture and cabinets, mouldings, and door and window components. Conversion into veneer and plywood is feasible with no specific processing requirements. With a calorific value of 4800-4900 kcal/kg, *A. mangium* provides good quality charcoal and is suitable for the manufacture of charcoal briquettes and artificial carbon. The pulp is readily bleached to high brightness levels and is excellent for papermaking. The neutral sulphite semi-chemical pulping of *A. mangium* gives yields of 61-75%. Wood also makes excellent particle board. With its dense foliage, retained throughout the year, *A. mangium* makes a useful shade tree, screening and soil cover crop. It can also serve as a wind or firebreak. *A. mangium* trees form a symbiosis with soil bacteria of the genus Rhizobium, leading to root nodules, in which the bacteria transform free nitrogen into organic and inorganic compounds containing nitrogen.

References

Adjers, G. and Srivastava, P.B.L. 1993. Nursery Practices (Chapter 6). *In*: *Acacia mangium*- Growing and Utilization. MPTS Monograph Series No. 3. Winrock International and FAO, Bangkok, Thailand, pp 1-75.

Darus, H.J.A. 1993. Vegetative Propagation. *In*: *Acacia mangium*- Growing and Utilization. MPTS Monograph Series No. 3. Winrock International and FAO, Bangkok, Thailand, pp 59-74.

FAO. 1987. Nitrogen Fixing Trees-A training Guide. RAPA Publication 1987/15, Bangkok, Thailand, pp 1-230.

Hutacharern, C. 1993. Insect Pests (Chapter 9). *In: Acacia mangium*- Growing and Utilization. MPTS Monograph Series No. 3. Winrock International and FAO, Bangkok, Thailand, pp 163-201.

Krisnawati, H. 2007 Modelling stand growth and yield for optimizing management of *Acacia mangium* plantations in Indonesia. PhD thesis, the University of Melbourne, Australia.

Krisnawati, H., Kallio, M. and Kanninen, M. 2011. *Acacia mangium* Wild: ecology, silviculture and productivity. CIFOR, Bogor, Indonesia, pp 1-15.

Mead, D.J. and Speechly, H.T. 1991. Growing *Acacia mangium* for high quality saw logs in Peninsular Malaysia. *In*: Abod, S.A., Tahir, P.M., Tsai, L.M., Shukor, N.A.A. and Sajap, A.S. (eds). Recent Developments in Tree Plantations of Humid/ Subhumid Tropics of Asia, pp 54–71. Malaysian Agricultural University, Serdang, Malaysia.

Mergen, F., Hodges, C., Nicholson, D.I., Popenoe, H.L. and Wiersum, K.F. 1983. Mangium and other acacias of the humid tropics. National Academy Press, Washington, DC, USA, pp 1- 62.

National Research Council. 1983. Mangium and other fast-growing Acacias for the humid tropics. National Academy Press, Washington, DC, USA.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry tree database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Nairobi, Kenya

Otsamo, R. 2002. Early effects of four fast-growing tree species and their planting density on ground vegetation in Imperata grasslands. *New Forests* 23: 1–17.

Pinyopusarerk, K., Liang, S.B. and Gunn, B.V. 1993.Taxonomy, distribution, biology and use as an exotic. *In*: Awang, K. and Taylor, D. (eds.) *Acacia mangium*: Growing and Utilization, 1–19. Winrock International and Food and Agriculture Organization of the United Nations, Bangkok, Thailand, pp 1-19.

Srivastava, P.B.L. 1993 Silvicultural practices. *In*: Awang, K. and Taylor, D. (eds) *Acacia mangium*: Growing and Utilization, Winrock International and Food and Agriculture Organization of the United Nations, Bangkok, Thailand. pp 113-148.

Zakaria, I. 1993. Reproductive Biology. *In:Acacia mangium* – Growing and Utilization. MPTS Monograph Series No. 3. Winrock International and FAO, Bangkok, Thailand, pp 21-34.

Chapter 2

Acacia nilotica (L.) Willd. Ex Delile

Family: Fabaceae – Mimosoideae
Common name: Babul, Kikar, Indian gum Arabic
Trade name: Babul
Origin: Botswana, Egypt, Eritrea, Ethiopia, India, Kenya, Mozambique, Namibia, Nigeria, Oman, Pakistan, Saudi Arabia, Sudan, Swaziland, Tanzania, Uganda, Yemen, Republic of Zambia, Zimbabwe

Botanical Characters

Acacia nilotica is a multipurpose nitrogen-fixing tree legume widespread in Africa and Asia, and occurs in Australia. It is an evergreen, usually moderate-sized tree with a short, thick and cylindrical trunk; bark is grey, reddish-brown or black, rough, furrowed. Leaves are alternate, bipinnately compound, 5-15 cm long; axis fairly hairy, with 3-8 pairs of side axes (pinnae) 1-4 cm long; leaflets 10-30 pairs on each side axis, small, narrowly oblong, 3-6 mm long, blunt at the ends with tiny hairs along edges, grey-green. Flowers are many, crowded, stalkless, 6-8 mm long, composed of 5-toothed corolla 3 mm long; many yellow, threadlike stamens, 6 mm long, united at base, with yellow, dot like anthers and pistil with slender ovary and threadlike style. Pods

Flowers of *Acacia nilotica*

are long, narrow, flattened, straight, mostly narrowed between seeds, stalked at the base, short, pointed grey or black, mostly aromatic, not splitting open, breaking in segments; seeds 8-15, beanlike, 7-9 mm in diameter, rounded, flattened, blackish-brown (Orwa et al. 2009). *A. nilotica* is generally accepted as a single, extremely variable species, divided into nine sub-species, three occurring in the Indian subcontinent and six throughout Africa (Brenan, 1983.) The sub-species are distinguished by shape, size and degree of pubescence on the pods, and the degree of pubescence on the branchlets. Shape of crown and habit are also important.

The three Asian sub-species, as described by Troup and Joshi (1983), are:

(1) *A. nilotica* subsp. *indica*, known as telia babul, teli or godi, the most common, economically important and extensively grown subspecies, with a spreading crown, bright brown shoots, smooth bark, and short, slender (and relatively few) spines;

(2) *A. nilotica* subsp. *subalata* (also common in East Africa), known as vedi, kaora or kauria babul, which is smaller than *A. nilotica* subsp. *indica*, with a shorter stem, a more spreading crown, more twisted and interlaced branches, a greyish-brown bark, stouter, whiter and longer spines, and flat pods which are a little constricted between the seeds. It is more common in the Deccan region; and

(3) *A. nilotica* subsp. *cupressiformis*, known as ramkanta or kabuli kikar, identified by its characteristic long, thin crown form. It produces inferior wood. It is found growing in Deccan, Punjab, Uttar Pradesh, Bombay and Gujarat region.

Distribution

A. nilotica is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia from Arabia eastward to India, Burma and Sri Lanka. It is distributed throughout the greater part of India in forest areas, roadsides, farmlands, tank foreshores, agricultural fields, village grazing lands, wastelands, bunds, along the national highways and railway lines. Mostly it occurs as an isolated tree and rarely found in patches to a limited extent in forests. It has been widely planted on farms throughout the plains of the Indian subcontinent. It is a species of Southern

Tropical dry deciduous forests and Southern Tropical thorn forests as distinguished by Champion and Seth (1968).

Silvicultural Requirements

A. nilotica is essentially a tree of semi-arid and arid areas restricted below 450 m elevation. It is generally found in plains, ravines and undulating ground. The absolute maximum shade temperature varies from 40 to 48 ^{0}C and minimum, 1 to 15^0 C. The frost and droughts are common in its zone of occurrence. The annual rainfall in its natural habitat varies from 200 to 1270 mm. It thrives best in areas with annual rainfall of about 500 to 1250 mm. It does not grow in areas receiving higher than 1500 mm annual rainfall except on gravelly porous soils. It does not withstand severe frost, hence it is completely absent above 300 m altitude (Luna, 1996).

It grows well in two types of soil: riverian alluvial and black cotton. It will not grow in hard soils which obstruct the penetration of roots, but can grow on saline and alkaline soils. It has a high resistance against oxygen deficiency in the soil and is, therefore, suitable for cultivation in swampy as well as stiff soils. Babul can grow in areas having a pH< 7.9 under poor drainage conditions.

Phenology

A. nilotica is seldom leafless, as new leaves appear immediately after the old leaves are being shed during March to June. Flowering season is irregular and differs from one locality to another, but it is usually from April to June in northern India and earlier in southern India. The trees begin to flower early from the age of three years and thereafter seed every year. The pods attain full size by February-March and ripen in May-June.

Propagation Technology

Through Seeds

A. nilotica seeds are available in abundance and can be collected from natural fruit fall, from standing trees or from felled trees. About 5-7-year-old saplings start producing seed. Seeds are black-

brown, smooth, compressed, 7-8 mm in diameter with a hard seed coat. Considerable variation exists in seed quality from one origin to another. Seeds from moist localities are generally bigger than those from a dry locality. Seed weight may vary from 5500 to 11,600 seeds/kg. Seeds can be stored in gunny bags, tins or baskets in cool and dry place with good air circulation. If seeds are to be stored for a long time, they need to be completely air dried and kept in airtight containers.

The seed coat of babul is very hard and impermeable. It requires pre-treatment to hasten germination by one of the following four methods:

i. Immersion in cold water for 48 hours
ii. Immersion in hot water (80^0C) for 30 minutes. Seeds are then soaked in ordinary water for 24 hours prior to sowing.
iii. Soaking in sulphuric acid (90%) for 10 to 30 minutes. Seeds after soaking in sulphuric acid are washed and dried prior to sowing.
iv. Seeds collected from goat/sheep pens do not need any further treatment and can be sown immediately after collection. This is probably the most convenient method. Animals may be fed with *A. nilotica* pods for this purpose.

Out of the above treatments the hot water treatment is safe, quick and effective and thus recommended.

The treated seeds are sown in nursery beds either by broadcast or dibbling method. However, the dibbling method is preferred. *A nilotica* is seldom raised in nursery beds. It is generally raised in polythene bags. Two or three treated seeds are sown in each bag, about 1.5 cm deep during February-March, i.e. about 5 months before transplanting in the field. The soil mixture used in polythene bags consists of soil and compost in 2:1 ratio. Germination commences 1 to 3 weeks after sowing and mostly completes in a month. The germination of the seed is epigeal. The radicle emerges and descends.

Vegetative Propagation

Vegetative propagation of *A. nilotica* is successful under mist chamber conditions. Success is reported in case of rooting of stem cuttings treated with indole acetic acid and indole butyric acid. Air

layering has also been tried successfully. Tissue culture propagation of *A. nilotica* has been successful with callus formation only.

Cultural Operations

Planting

Direct sowing is the easiest and most common method for raising babul plantation in the field. Several methods have given satisfactory results. The successful ones are by broadcast sowing (seed rate 2.5-3 kg/ha), dibbling in lines, patches or mound sowing during June (seed rate 1 kg/ha). The seedlings are generally planted in 30 cm x 30 cm x 30 cm pits. The most common spacing adopted for plantation is 4 m x 4 m. On road sides, deeper pits of the size 45 cm x 45 cm x 45 cm are preferred. Mound planting is practiced where there is a risk of waterlogging specially on dug up road sides. For proper growth and survival it is necessary to give one or two watering after planting. Higher survival rate and better rate of growth is reported when soil and water conservation measures are also adopted.

Tending Operations

In areas where growth of grasses and understorey vegetation is dense, it is almost impossible to raise babul without proper weeding. In the first year of plantation, three weedings are usually necessary. When babul is grown in dry areas mulching is generally recommended in the first year. Mulching needs to be carried out during November-December for optimum results. When babul is planted in close spacing, cleanings and thinnings become necessary. Tending operations must be carried out for the first five years for the seedlings to develop into a vigorous and healthy crop.

Tree Protection

Pests

A. nilotica can be damaged by many groups of insect pests (Coleoptera, Lepidoptera, Hemiptera and Orthoptera). *Celosterna scabrator* and *Oxyrachis tarandus* are reported to be the most notorious in various localities. The mango mealy bug *Drosicha*

stebbingi, primary pests of *Mangifera indica* also attack *A. nilotica*. The important pests and their control measures are given in the Table 1.

Table 1. Important pests and their control

Pests	Order	Family	Tissue(s) damaged	Nature	Control measures
Celosterna scabrator (Larvae)	Coleoptera	Crambycidae	Roots of young trees	Bore down wards, hollowing	Root should be drenched with 0.3% emulsion of Aldrin.
Araecerus suturalis (Adult)	Coleoptera	Anthribidae	Seed	Stored Seed	Insect pest feeding on the pods or seeds are controlled by spraying Endosulfan or tetrachlorovinphos spray of Malathion
Chrysobothris gardeni (Larvae)	Coleoptera	Buprestidae	Root	Bore in the root	Root should be drenched with 0.3% emulsion of Aldrin.
Diapromorpha balteata (Adult)	Coleoptera	Chrysomelidae	Foliage	Feeds on foilage	Broad spectrum insecticides, Malathion, Savin, Endosulfan, Monochrotophos
Drosicha stebbingii (Adult)	Hemiptera	Margardidae	Leaf, shoot and branches	Feeds at the sites of wounded tissues	Fumigants like petrol carbon disulphide mixture in an insectiplaincidal, emulsion like 0.1% Endosulfan
Oxyrachis sp. (Adult)	Hemiptera	Membracidae	Leaf, shoot, and branches	Lays eggs in a slit on a shoot	Root should be drenched with 0.3% emulsion of Aldrin, spraying of 0.1% Carbaryl and 0.2% monochrotophos

Diseases

Almost all the stages of the plant are affected by different fungal pathogens. The common species of fungi, the diseases they cause, and control measures are given in Table 2.

Table 2. Important diseases and their control

Pathogens	Class	Disease	Control measures
Ganoderma lucidum	Basidiomycontina	Ganoderma root rot	Site preparation: Clear felling removal of old stumps and residual roots and root lets
G. applanatum	Basidiomycontina	Decay of Wood	-do-
Polyporus gilvus	Basidiomycontina	Root rot	Avoiding waterlogging conditions and injury to plants
Botrydiplodia theobromae	Deuteromycontina	Collar rot	Soil drenching with Carbendazin fungicides
B. theobromae	Deuteromycontina	Dieback	Cu-based fungicides like Blitox (0.2%)
Rhizoctonia bataticola	Deuteromycontina	Charcol	Spraying with Dithane or Root-rot Bavistin (0.1%) fungicides
Fusarium sp.	Deuteromycontina	Fusarium	Avoiding excessive water wilting

Suitable Agroforestry Systems

A. nilotica + rice is a traditional agroforestry system in central India. The farms have an average of 20 babul trees per hectare in upland rice fields, while the tree-stand density being greater on smaller than on larger farms (>8 ha). Over a 10-year rotation period, the trees provide a variety of products such as fuelwood (30 kg/tree), brushwood for fencing (4 kg/tree), small timber for farm implements and furniture (0.2 cu m), and non-timber products such as gum and seeds. The babul + rice system was estimated to have a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a 10-year period, though at a low level of income. Babul trees account for nearly 10% of the annual farm income of smallholder farmers (<2 ha) (Viswanath et al. 2000).

Yield

Babul forests are generally managed on a rotation of 30 to 40 years. Trees planted in agroforestry plantations are generally harvested on shorter rotations. In forests, the trees are generally marked for felling during December-January and felling is carried out from February to April. The timber and firewood are sorted out and timber is generally transported to depots by April-May. Harvesting is completed by June before the onset of monsoon. In dry areas, the rate of growth is poor. Babul attains 10 to 12 m height at 25

***Acacia nilotica* plantation**

years in dry tracts where it is capable of yielding a mean annual increment of 3 to 4 m^3/ha.

Utilization

Babul produces very strong, tough and heavy timber with a specific gravity of 0.670 and is nearly twice as hard as teak. It is hard and tough to work and saw especially when seasoned.

Babul is a very useful species and yields several products, including timber, firewood, bark gum and fodder leaves. Timber is used for construction and for agricultural implements like harrows, ploughs, bullock cart yokes, shafts and wheels etc. It is also used in several sports and athletic goods, like clubs, wall bars, pebble bars, etc., as well as for class one type tool handles. The branches of the tree make excellent fuelwood. The wood makes excellent fuel, and the calorific value of heartwood is 4946 kcal/kg. The wood yields a high grade charcoal. The average weight is about 785 kg/m^3 at 12% moisture content. It is somewhat coarse-textured and has interlocked grains. The wood is dull and somewhat rough without any characteristic odour or taste. The wood is also used for paper and pulp making.

The bark of the tree is separated from the logs and used for tanning by local tanneries. The average tannin content in bark is estimated at 12%, though sometimes it can be as high as 20%. Bark of older trees is richer in tannin than of younger ones. The leaves and pods are used as fodder by graziers locally. Pods are also used for tanning purposes. Almost all the products obtained from *A. nilotica* are marketable. The tree yields a black gum known as Amravati gum and used for matches, ink paints, calico-printing etc. The gum obtained from *A. nilotica* is known as Indian gum Arabic.

References

Brenan, J.P.M. 1983. Manual on taxonomy of *Acacia* species: present taxonomy of four species of *Acacia (A. albida, A. senegal, A. nilotica, A. tortilis)*. FAO, Rome, Italy. 47 pp.

Champion, H. G. and Seth, S. K. 1968. A Revised Survey of the Forest Types of India. Manager of Publicatons, Delhi. 404 pp.

Luna, R.K. 1996. Plantation Trees. IBD Publisher, Dehradun, India

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry tree

database: a tree reference and selection guide version 4.0. World Agroforestry Centre, Nairobi, Kenya

Troup, R.S. and Joshi, H.B. 1983. The Silviculture of Indian Trees. Volume IV. Leguminosae. Govenment of India Press, Nasik, India.

Viswanath, S., Nair, P. K. R., Kaushik, P. and Prakasam, U. 2000. *Acacia nilotica* trees in rice fields: A traditional agroforestry system in central India. *Agroforestry Systems* 50: 157–177.

Chapter 3

Ailanthus excelsa Roxb

Family: Simarubiaceae
Common name: Tree of Heaven, Ardu
Trade name: Maharukh
Origin: India and Sri Lanka

Botanical Characters

Ailanthus excelsa is a large deciduous tree, 18-25 m tall and 60-80 cm in diameter. The tree bark is light grey and smooth, becoming grey-brown and rough on large trees. Leaves alternate, pinnately compound, large, 30-60 cm or more in length; leaflets 8-14 or more pairs, long stalked, ovate or broadly lance shaped from very unequal base, 6-10 cm long, 3-5 cm wide, often curved, long pointed, hairy gland; edges

A fully mature tree of *Ailanthus excelsa*

Flowers of *Ailanthus excelsa*

coarsely toothed and often lobed. Flower clusters droop at leaf bases, shorter than leaves, much branched; flowers many, mostly male and female on different trees, short stalked, greenish-yellow; calyx 5 lobed; 5 narrow petals spreading 6 mm across; stamens 10; on other flowers, 2-5 separate pistils, each with elliptical ovary, 1 ovule, and slender style. Fruit, a one-seeded samara, lance shaped, flat, pointed at ends, 5 cm long, 1 cm wide, copper red, strongly veined, twisted at the base.

Distribution

A. excelsa is considered native to the Indian Peninsula. It occurs throughout the tropical and sub-tropical regions of India, especially in the dry districts of Gujarat, Rajasthan, Haryana, Punjab, Uttar Pradesh, Bihar, Odisha and the Deccan plateau. It is not found in high-rainfall regions of the West Coast. It grows well in semi-arid and semi-moist regions and has been found suitable for planting in dry areas with an annual rainfall of about 400 mm. It is commonly found in mixed deciduous forests and some sal forests, but is rare in moist areas with high monsoons.

Phenology

The panicles of small yellowish flowers appear in February–March and the fruits ripen in May–June. Old leaves fall during February and new ones appear in March–April. In Central India, flowers appear during February and March and in the North during April.

Silvicultural Requirements

A. excelsa is a strong light demander. In its natural habitat the absolute maximum shade temperature varies from 45 to 47.5 ^{0}C and the absolute minimum from 0 to 12.5 ^{0}C. The mean maximum temperature in May is generally the highest. The temperature varies from 30 to 42.5 ^{0}C. The mean daily minimum temperature in January, the coldest month of the year, varies from 4 to 21 ^{0}C. The mean annual rainfall ranges from 500 to 1900 mm, sometimes even up to 2500 mm. It is sensitive to drought and is moderately frost tender. The mean relative humidity ranges from 40 to 80% in January and from 60 to 90% in July. It has been found to be a suitable species for planting in dry areas of Rajasthan with an annual rainfall of about 400 mm. It avoids moist areas having high monsoon rainfall.

It can grow on a variety of soils but thrives best on porous sandy loams. It avoids clayey soils with poor drainage and waterlogged areas. It can grow even on shallow dry soils but the growth is poor.

A. excelsa gives better performance than other species in lateritic soils. It is a relatively salt-tolerant species. The tree can be seen growing up to an elevation of 900 metres.

Propagation Technology

Through Seeds

Natural regeneration of *A. excelsa* in the forest is usually not satisfactory. The seeds are very light and winged and are dispersed far and wide by the wind. If the seeds fall on bare ground germination takes place early in the first rainy season, but the seedlings rarely survive due to their sensitiveness to and intolerance of heavy weed growth. The seeds which are buried deep fail to germinate and seedlings in depression die due to poor drainage, weed competition and attack of pests.

The seeds are separated, dried and stored in sealed airtight tins. Their normal viability is 4-5 months, but under proper storage conditions they can remain viable for up to 240 days. The nursery soil should be light, porous and well drained. Indofil may be mixed with the soil to avoid insects and ants. The seedbeds should be

well raised to allow drainage. Sowing should be done in seedbeds or mother beds in December–January. After broadcasting, cover the seed lightly with about 1 cm of sand. Only mild watering is required. Excess water will lead to damping off disease in seedlings. The germination is epigeal, it starts 8-14 days after sowing and completes in 40-45 days. No seed pre-treatment is required. After 3 weeks of maintenance, seedlings can be transplanted into 10 cm x 20 cm polybags. From one kg of seeds about 1425 healthy seedlings can be obtained. About 15 g of seeds are required for sowing 1 sq. m of bed. Mixing of seeds with ash or pulverized soil ensures uniform sowing. The germination percentage is nearly 60-70. Thirty to 45 days old seedlings from mother beds are pricked out into plastic or other containers and kept till they become fit for planting. Soil, sand and farm yard manure in the ratio 3:2:1 is generally used as potting mixture. Application of urea mixed with water boosts plant growth.

Through Vegetative Propagation

The cuttings raised in polybags can be used as planting stock after they sprout and root. *A. excelsa* can also be planted by root shoot cuttings 2-3 cm in diameter, prepared from nearly one-year-old seedlings. Stump planting has given only 50% success. Natural regeneration through coppices and root suckers is adequate. Coppice shoots are thinned for better development.

Grafting Techniques

A simple grafting technique for mature *A. excelsa* trees was developed by the Arid Forest Research Institute (AFRI), Jodhpur. One-year-old seedling root stocks were grafted with two months old scions collected from 7- to 10-year old trees, using wedge and patch

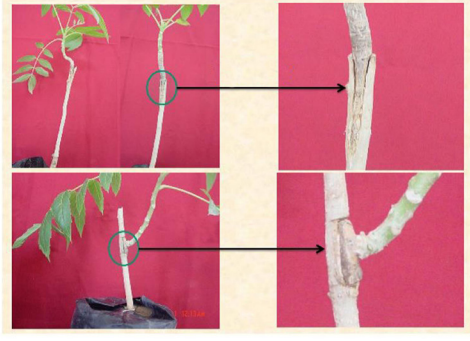


Fig. 1. Grafting techniques in *Ailanthus excelsa* (upper, wedge graft; lower, patch graft) (Source: AFRI, Jodhpur)

grafting methods, from February to April. It is important that the scion should have the same thickness as of seedling rootstock for better compatibility in tissues. Graft unions were wrapped with parafilm strip to avoid desiccation and pathological problems (Fig. 1). Grafted plants were kept in mist poly house initially for 2 weeks in 80% relative humidity. Thereafter, they were hardened in shade house for another 8-10 weeks. Wedge grafting is more successful (grafting success ≈ 50%) than patch grafting.

Attempts were made to develop clonal techniques to induce rooting in stem cuttings (Sharma and Tomar, 2003) and through tissue culture techniques (Parveen and Tomar, 2009). However, success rate of macro propagation was very poor (5% with stem cuttings) and in the case of micro propagation rooting was 50% and hardening success was still poor.

Cultural Operations

A. excelsa prefers sandy and porous soils. It can grow on slopes and on stony patches under suitable moisture conditions. Too moist or waterlogged and frost-prone areas should not be selected.

Planting

After selecting the site, the area is cleared and 30 cm^3 or 45 cm^3 pits are dug in Feb-Mar and the soil is allowed to weather. Planting in the pits is carried out in July. For block planting nursery-raised 6 to 10 months old seedlings are used in pits at a spacing of 3 m x 3 m or 5 m x 5 m. The seedlings that attain a height of 50-100 cm are suitable for planting. The root shoot ratio of 1:2 is considered good for stump planting. The row and line planting is carried out by planting saplings. A spacing of 5 m is maintained in case of row or line planting.

Regular watering and protection from animals is required till the saplings get established.

Tending Operations

Timely and regular weeding for the first two years and soil working stimulates growth. Weeding should be carried out three times in the first year in July, August and October. In the second year one

Lopped trees of *Ailanthus excelsa*

weeding is needed in August. Weeding should always be accompanied by hoeing, soil working, mulching and casualty replacement. Bushes likely to shade the plants should be removed.

Complete crown lopping significantly affects the dbh (trunk diameter at breast height). The effect of lopping on fodder production was also found significant. Two-thirds of crown lopping was found suitable for better growth and sustainable fodder yield. The lopping is commenced from the fourth year onwards; i.e. leaf fodder from one tree is available for at least 30 yrs.

Thinning is generally required under block planting. The first silvicultural thinning may be carried out in the third or the fourth year when the tree attains a height of 6-8 m. Fencing is also needed in areas where goats and sheep are browsed.

Tree Protection

In nursery, seedlings are susceptible to damping off disease; so only an optimum level of moisture should be maintained. The growth is retarded considerably in January. Seedlings are prone to porcupine damage, and susceptible to insect attack and suppression by weeds. For controlling insect pests, spraying or dusting with BHC insecticide is carried out. The seedlings or saplings may be affected by web worm *Atteva fabriciella*. Severe defoliation affects plant growth and may cause death of the plant. The full grown larvae

are grey in colour and live gregariously under a silk web spun over the leaves and shoots. They are controlled by application of 0.1% of Malathion. *Batocera rufomaculata* is another serious pest which bores into the stems of young trees. The larvae bore irregular and extensive galleries. Spraying of kerosene or fuel oil is done in the larvae tunnels or the tunnels are plugged with cotton saturated with kerosene oil. Sometimes the bottom portion of the trunk is completely hollowed and the tree is blown down by wind. *Atteva niveigutta* and *Eligma narcissus* are other serious defoliators which can be controlled by contact insecticides such as chlordimeform or Sevin (0.01-0.02%) or Sumicidin (0.01 – 0.02%). The leaf spot is caused by *Cercospora ailanthicola, C. glandulosa, C. simarrubacienses* and *Alternaria* sp. The disease appears in the form of necrotic spots on leaves. The control measures include foliar spray of Bavistin or Dithane M-45 (0.2%) at fortnightly intervals.

Suitable Agroforestry Systems

A. excelsa is a fast-growing fodder tree that could be propagated in association with forage and food crops without jeopardizing their production. In an agroforestry system, 100 plants of *A. excelsa* are recommended for a one-hectare area for achieving higher fodder production without impairing the soil fertility and crop production In this system, the soil is also enriched in nitrogen, phosphorus, carbon, sulphur, etc. over a period of few years in spite of the fact that biomass is annually harvested as forage. Mostly wheat, millet, barley, mustard, pulses and guar crops are grown in association with this tree species. It was found that 2500 kg/ha of wheat and 1250

***Ailanthus excelsa* based silvi-pasture (left) and agri-silviculture systems**

kg/ha of barley could be produced when sown in the intermittent spacing of 10 m x 10 m of *A. excelsa* plantation.

Trees are planted at the north and west boundaries of the fields in order to reduce wind velocity which could otherwise cause higher moisture losses from crop field due to advection.

Silvipasture system of *A. excels* is quite popular among the farmers. Different tier systems of fodder production are practised. Multi-tier systems provided maximum dry fodder and seed/ grains with the highest net returns followed by two-tier and single-tier systems. Different forage crops, viz. *Cenchrus ciliaris, Cenchrus setigerus* and *Panicum antidotale* are grown in association with *Ailanthus excelsa*. *C. setigerus* produced higher forage yield than other grasses.

Yield

The crop rotation period suitable for *A. excelsa* is 20 years when it attains a diameter of 20 cm or more. In Tamil Nadu, about 50-75 t/ha at a rotation of 5-6 years was realized through seed-raised plantations in unirrigated conditions. But in the irrigated conditions the yield rose to 120-135 t/ha in 5-6 years rotations (Rajasugunasekar, 2014). Lopping of the trees is started from the fourth year onwards. It was observed that lopping after 7 years resulted in better fodder yield. For leaf fodder, complete crown lopping is done twice or thrice a year. Mostly lopping is done during November–January and May–July. Consequently, these are the peak months of the availability of *A. excelsa* leaves in the market. During February–April, fodder availability is less due to shedding of old leaves and flowering and fruiting season. The branches can be used as small timber and should be cut after rainy season from well-grown trees. It is estimated that an average tree gives about 100, 200, and >400 kg green leaf fodder per year at the age of 5, 10 and >20 years, respectively.

Utilization

A. excelsa wood density is low; therefore, it is not suitable for heavy or moderate structural works. Wood is straight grained, fairly even and very coarse textured. It is soft but fairly strong and holds nails

well. Annual growth rings are indistinct. It is very easy to saw and work both by hand and machines. The timber is very light and perishable and the air-dried weight is 12.25 kg/cubic ft. The timber is likely to develop fine, long, widely spaced surface cracks. It is also liable to blue stain. Therefore, it could be used in many other light applications such as light constructions, boat building, veneer, decoration, and matches industry.

The wood is used for packing cases, fishing floats and sword sheaths. It is also used as Grade III and Grade IV plywood. The pulp is obtained from debarked wood and is used in paper industry as a substitute for aspen. It improves the surface quality of paper. Wood of the plant is extensively used for making matchwood boxes and match splints. The wood is extensively used in cottage industries for making wooden toys and cheap quality cricket bats. The leaves are rated as highly palatable and protein rich nutritious fodder for sheep and goats and are said to augment milk production. The tree is, therefore, largely planted on farm lands. An average tree yields about 500 to 700 kg of green leaves twice a year. Some trees are lopped for green leaves while leaves from other lopped trees can be dried and stored to be used during feed-shortage periods. The green leaves in some places are even marketed. They are highly palatable and easily digestible; animals relish them better than the dry leaves even when the latter are treated with molasses to improve their palatability.

A. excelsa is resistant to drought and soil conditions. It grows well on slopes. The species has been extensively used for soil conservation purposes. It grows well as a shade and avenue tree along the road side in Rajasthan and, indeed, almost throughout the hotter parts of India. It has also been used successfully for planting around the margins of cultivated fields. It is suitable for degraded and denuded areas and wastelands. It grows well in arid and semi-arid regions as well as in plains and hills.

References

Parveen and Tomar, U.K. 2009. *In vitro* high frequency of adventitious shoot regeneration from hypocotyls segment of *Ailanthus excelsa* Roxb. *Annals of. Forestry* 17: 21-26.

Rajasugunasekar, D. 2014. Cultivation techniques of *Ailanthus excelsa*. *In* Transfer of Tree Cultivation Technologies to Krishi Vigyan Kendras (KVKs) of Tamil Nadu and Puducherry. Institute of Forest Genetics and Tree Breeding, Coimbatore, India, pp 19-22.

Sharma, N. and Tomar, U.K. 2003. Vegetative propagation of *Ailanthus excelsa* through stem cuttings. *My Forest* 39 (3): 299-308.

Chapter 4

Alnus nepalensis D.Don

Family: Betulaceae
Common name: Alder, Nepalese alder, Himalayan alder, Indian alder
Trade name: Alder
Origin: Bhutan, Cambodia, China, India, Japan, Laos, Myanmar, Nepal, Thailand, Vietnam

Botanical Characters

Alnus nepalensis is a deciduous or semi-deciduous tree with a straight trunk, up to 30 m in height and 60 cm in diameter; bark dark grey, often with yellowish patches and slightly raised lenticels. Leaves alternate, elliptical, ovate to oblong, 6-21 cm long, 4-10 cm wide, entire, denticulate or sinuate, shallowly crenate to sub-entire, rounded or cuneate at the base, with 12-16 pairs of lateral veins, top surface dull or shiny dark green, undersurface pale with dot-like, yellow-brown scales; petiole strong, 1.5-2 cm long. Narrowly cylindrical clusters of tiny flowers or catkins occur in autumn as males or females, separate on the same or different twigs; male catkins grouped in a terminal panicle up to 16 cm long; catkins yellow, 10-16 cm (25 cm max.) long, hanging in clusters at the end of twigs; female inflorescence grouped in a short, axillary raceme of 3-8 catkins; catkin 1-1.7 x 0.6-0.7 cm, erect, woody, occurring on branching side twigs; peduncle 3-6 mm long. Fruits, which resemble the

Catkins (left) and fruits of *Alnus nepalensis*

cones of the pine family, are dark brown, upright on short stalks, elliptical, composed of many spreading, hardwood scales; seeds light brown, circular and flat with 2 broad, membranous wings, more than 2 mm across (Orwa et al. 2009).

Distribution

A. nepalensis grows between 1000 m and 2500 m elevation belt most predominantly in the eastern Himalaya which encompasses eastern Nepal, Sikkim, Darjeeling, Bhutan, Arunachal Pradesh, Nagaland and the Khasi hills of Meghalaya. It is a pioneer species on freshly exposed landslide soils. It grows on sandy eroded soils, denuded habitats, rocky slopes, landslide-affected slopes, steep stream sides and in natural areas. It has been a common species in natural forests and recently has also become an important species of plantation forests in the Sikkim Himalaya. It has been considered as a useful species in social forestry and agroforestry in the region.

Silvicultural Requirements

A. nepalensis prefers moist, cool climates with mean annual temperature of 13-26 °C and mature trees are tolerant to frost. It can grow at high altitudes in both temperate and sub-tropical regions, with annual rainfall ranging from 500 to 2500 mm and a dry season extending to about 6 months. It is drought tolerant, but best growth is obtained in areas where the mean annual rainfall exceeds 800 mm and the relative humidity is higher than 70%.

The tree prefers moist and well-drained soils, including loam and loamy sand gravel, sand and clay. It does not require high soil fertility but prefers permeable soils. It grows well on soils with high water content but not on waterlogged soils. It does poorly on dry, exposed ridge tops. At lower altitudes particularly, *A. nepalensis* occurs on moist sites, such as near rivers and in ravines, but it will colonize on rocky sites exposed by landslips, or lands abandoned following cultivation.

Phenology

A. nepalensis flowers during September–October, the male in large terminal drooping panicles and female flowers in small axillary

racemes. Fruit ripens during December–March. Empty cones remain for long on the tree.

Propagation Technology

Through Seeds

The catkins are collected directly from the tree when they turn yellowish-brown and begin to open, but before the seeds have been dispersed by the wind. Catkins from previous years can persist on the tree; they are dark brown or black, contain no seeds and should be avoided. After harvest the catkins are dried in the sun until they open and release the seed. The seeds are orthodox. Seed viability can be retained for at least a year in hermetic storage at 4-5 °C with 5-10% moisture content.

Pre-treatment of seeds is not necessary. Some experts, however, recommend soaking in warm water before sowing. The nursery beds need to be carefully prepared, incorporating soil collected from mature *A. nepalensis* forests (to ensure suitable symbionts are present), and made level. Seeds are broadcasted at 15 kg/ha, or sown in lines, and then covered with a thin layer of fine soil with a further covering of rice straw, pine needles, or a plastic film. Germination starts 1-2 weeks after sowing and is completed within 2 weeks. Transplanting into containers can begin 4-5 weeks after germination. Seedlings are thinned out during the rainy season when they have produced 6 leaves and attained a height of 2-3 cm, at which stage they need to be watered and tended regularly. Young seedlings are liable to damage by ants and defoliation by frost and are very often killed.

Cultural Operations

Planting

Site preparation is very important as weed growth can easily outgrow young seedlings. In general, the site should be cleared of vegetation, ploughed, or herbicide-killed before planting. Most

planting is done with containerized seedlings. However, bare-rooted seedlings have proven successful given proper lifting and handling. A spacing of 2.5 m × 2.5 m is commonly used for plantations, although closer spacing is desirable for a fuelwood crop. Wildings (natural seedlings) have also been used successfully, especially on north-facing slopes. Direct sowing is an alternative. The seed must be fresh and have a high germination capacity. Ample quantities should be used, and the seed be sown on exposed mineral soils. Good results are obtained when soil from under old trees is mixed with seed to facilitate even broadcasting and to introduce Frankia. Vegetative propagation has been unsuccessful (Lohani et al. 1980).

Tending Operations

A. nepalensis is pollarded for posts. On good sites, poles and fuelwood can be harvested after 5 years. Small diameter timber can be harvested in less than 10 years. Longer rotations are needed for ordinary saw timber. The species coppices after cutting, but successful regrowth seems to depend on seasonal and locality variations, with wet season felling and moist localities being best. Trees develop an extensive lateral root system and are fast growing. *Alnus* spp. are very susceptible to wind damage.

Tree Protection

A. nepalensis is highly vulnerable to attack by defoliators *Anomala* spp. and *Oreina* spp. The stem borers *Batocera* spp. and possibly *Zeuzera* spp. may also attack the tree. An aphid, *Eutrichosiphum alnifoliae*, is a pest of economic importance, and ants usually attack young plants. Suitable pesticides should be used to control the pests.

Suitable Agroforestry Systems

Cardamom-based traditional agroforestry systems are prevalent in eastern Himalaya. The large cardamom is a perennial cash crop grown traditionally beneath the natural forest tree cover on marginal lands and slopes. It is a shade loving plant and requires high moisture and is usually cultivated in areas where mean annual rainfall varies

between 1500 and 3500 mm. Majority of cardamom plantations have *A.nepalensis* as shade trees since the combination with cardamom is sympatric and has proved to be ecologically and economically viable (Sharma et al. 2007). It provides fuelwood for both cardamom-curing and domestic use. Trees attaining more than 25-30 years age provide timber.

Shifting agriculture or jhum is the major economic activity in the north-eastern India. *A. nepalensis* has been an important fallow species in the jhum system that is traditionally valued and conserved by jhum farmers. The tree serves as a shade for pine apple cultivation.

Utilization

A. nepalensis gives stability to slopes that tend to slip and erode. Its seeds have been broadcast to stabilize landslides area. It is inter-planted with annual crops and used as a shade tree for *Cinchona officinalis* (quinine) and *Amomum subulatum* (large cardamom). It has been effectively used to reforest abandoned shifting cultivated areas because it grows as a pioneer tree species in degraded habitats with low fertility soils. It is also planted to improve the stability of slopes liable to erosion and landslides, and for mine reclamation. *A. nepalensis* forms a symbiosis with nitrogen-fixing actinomycetes of the genus Frankia and is, therefore, able to improve degraded lands. The species can fix 50-150 kg N per ha. Considerable quantities of nutrients are recycled through the litter of *Alnus* spp. The tree may produce a leaf and twig litter of 3-6 t/ha, containing N 3.4-3.7 g, P 0.08-0.1 g, K 0.6-0.7 g and Ca 0.2 g per 100 g dry matter.

On terraced slopes, the species is commonly pollarded for poles and interplanted with crops like maize, barley, chilli and pumpkin. The cultivation of large cardamom or *Cinchona* spp. trees in combination with *A. nepalensis* is a common practice in the central Himalayas. The foliage is of low to moderate value as fodder for sheep and goats; it is not suitable for cattle. Wood has a low calorific value. It dries easily, burns well and is an important source of firewood and charcoal. It has an even grain, seasons fairly well, and is easy to saw and finish by hand or machine. The wood preserves fairly well but is perishable if subjected to alternately wet

and dry conditions. It is also subject to discolouration by oxidation and fungal sap stain. It is suitable for boxes, splints and matches, poles, general carpentry, furniture parts, turnery and newsprint.

References

Lohani, D. N., Joshi, R. C. and Dwivedi, B. N. 1980. Vegetative propagation of forest species. UP Forest Bulletin, No.41. 10 pp.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009 Agroforestry tree database: a tree reference and selection guide version 4.0. International Centre for Agroforestry Research, Nairobi, Kenya

Sharma, R., Xu, J. and Sharma, G. 2007. Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. *Tropical Ecology* 48 (2): 189-200.

Chapter 5

Anthocephalus cadamba
(Roxb.) Miq.

Family: Rubiaceae
Common name: Kadamb, cadamba
Trade name: Kadamb
Origin: India, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore and Vietnam

Botanical Characters

Anthocephalus cadamba, synonymous to *Neolamarckia cadamba,* is a large tree with a broad umbrella-shaped crown and straight cylindrical bole The branches are characteristically arranged in tiers. The tree may reach a height of 45 m with a stem diameter of 100–160 cm and sometimes it has a small buttress up to 2 m high. The bark is grey, smooth and very light in young trees, but rough and longitudinally fissured in old trees. The branches spread

Fruit (left) and a sapling of *Anthocephalus cadamba*.

horizontally and drop at the tip. The leaves are glossy green, opposite, simple sessile to petiolate, ovate to elliptical (15–50 cm long by 8–25 cm wide). In young fertilised trees, the leaves are much larger, subordinate at base and acuminate at apex; the stipules are interpetiolar, narrowly triangular and deciduous. The fruitlets are numerous, somewhat fleshy, with their upper parts containing 4 hollow or solid structures. The fruit occurs in small, fleshy capsules packed closely together to form a fleshy yellow-orange infructescence containing approximately 8000 seeds. The seeds are somewhat trigonal or irregular shaped, not winged (Soerianegara and Lemmens, 1993).

Distribution

A. cadamba is a tree of Indo-Malayan region. It occurs in the sub-Himalayan tract from Nepal eastwards, extending through West Bengal and Assam into Burma, Nepal and Sri Lanka, Malaysia across Indonesia and Borneo to the Philippines and New Guinea. In the Peninsular India, it is found in Chota Nagpur of Bihar, Raipur and Bilaspur districts of Madhya Pradesh, Northern Circars tract of Andhra Pradesh and the evergreen forest of Karnataka; southwards to Trivandrum in Kerala (Anon, 1985). It is a constituent of southern tropical semi-evergreen forests, secondary north Indian tropical moist deciduous forest and tropical fresh water swamp forest according to the classification by Champion and Seth (1968). It also occurs in the tropical semi-evergreen and evergreen forest up to an elevation of 900 m in all districts of Arunachal Pradesh. The tree is commonly cultivated in many parts of the country in gardens. In West Bengal, it has been grown in plantations for a fairly long time.

Silvicultural Requirements

In the natural habitat of *A. cadamba*, the absolute maximum shade temperature varies from 37.5 to 47.5 °C and the absolute minimum from 0 to 15 °C. Light is the most important condition for good growth. The tree is sensitive to frost. The normal rainfall ranges from 1500 to 5000 mm, received mainly during May–September.

The tree can endure dry periods lasting upto 3 months without suffering any damage. However, some *A. cadamba* trees may also grow locally on much drier sites with as little as 200 mm annual rainfall.

A. cadamba is a typical pioneer species that grows best on deep, moist, alluvial sites, and often in secondary forests along riverbanks and in the transitional zone between swampy, permanently flooded and periodically flooded areas. It is found growing on freshly exposed soils due to landslides, exposed slope and degraded soils exhibiting the character of a long-lived pioneer species. It also grows in the sandy soils of Brahmaputra valley. The species is considered suitable for soil conservation, agroforestry, jhum, and land reclamation. The range of the altitude for growing is between 300 and 800 m above sea level. In the equator region it is found from just above sea level up to an elevation of 1000 m (Martawijaya et al. 1989)

Phenology

The tree is leafless or nearly so in the hot season. The small orange coloured highly scented flowers in globose heads appear chiefly from May to July. The fruits ripen towards the end of rains in August to October and fall in January–February. The tree starts flowering and fruiting at an early age of 6 to 7 years.

Propagation Technology

Through Seeds

The ripened fruits are orange in colour, harvested from the trees during September to December by climbing or shaking the branches after spreading collection sheets on the ground. The seeds are mature when the fruit has changed colour to dark brown. The collected fruits can be allowed to rot for three to four days and pulp is then washed off by hand in a bucket of water; seeds settled at the bottom are taken out and dried well. Or, the fruits may be rubbed to form a paste like slurry, which is passed through a 0.50 mm sieve plate and shaken

vigorously (Vijayaraghavan, 2014). The blackish paste sieved through the plate is collected into a pan and dried to extract seeds. Each fruit on an average yields 456 mg of seeds. Another method is by cutting the fruits into small parts and allowing them to dry and after a few days crush the small parts and separate the seeds. One gram has around 23,000 to 25,000 seeds..

Seeds can remain viable for up to 6 months at an ambient temperature (Joker, 2000). According to Martawijaya et al. (1989), dried seeds stored in airtight containers in a moist room will retain viability for about one year. The germination rate of fresh seeds is variable, but generally low at about 25%. When seeds are stored in cool, airtight boxes for about 2.5 months, a much higher germination rate (up to 95%) can be obtained.

Because of their small size, the seeds are mixed with fine sand (1:10) and sown in seedbeds. The sieved seeds need no pre-sowing treatment. Seeds of about 0.1g (about 2500 seeds) can be sown in galvanized or wooden trays filled with fine river sand and soil and treated with fungicide. The seeds better be mixed with sterilized sand before sowing. They are sown in February at the rate of about 0.2 gm of seed per m^2 of bed. Winter sowing is not successful. Percentage of germination is high.

The germination of *A.cadamba* seeds in open beds is generally difficult. Therefore, plants are invariably raised in shaded beds to exclude insolation and splashing effects of rain water. Before sowing, the beds are thoroughly wetted and seeds are broadcast on the top taking care that they do not get buried in the soil, instead they are patted with hand. Germination takes place in about three weeks. The germination percentage is 60-90. The seedlings from the tray can be pricked and transplanted in polybag containers with fungicide after attaining a height of 5 cm. Shade cover is needed after transplanting. Growth is fast under tropical conditions and seedlings could reach plantable size (30 cm) in 4 to 5 months. Seedlings require periodic watering in the first stages of development. Common mistakes in propagation are over-watering and associated disease problems, over-shading and allowing the germinants to become too large for easy transplanting leading to malformed tap roots or root curling in the pots. About 200,000 seedlings can be obtained from 1 kg of

seeds in nurseries. Out planting is done with 35-50 cm tall seedlings. The seedbeds should be protected from heavy rain and not watered too much as damping-off can be a problem. To prevent damping-off disease, seedlings should be placed in well-ventilated conditions. A mild fungicidal spray may also be used to prevent the damping-off disease (Vijayaraghavan, 2014).

Through Vegetative Propagation

It has been reported that Indole butyric acid (IBA) and Napthaleneacetic acid (NAA) at 500 ppm treatments give better results than other treatments (Vijayaraghavan, 2014). Sometimes the treatment with 5000 ppm of IBA during rooting and survival in air layering can be valuable. Coppicing is another method used for regeneration in *A. cadamba.*

Cultural Operations

Planting

The soil should be well drained and not vulnerable to flooding. *A. cadamba* seedlings of one year age are planted at 5 m × 5 m spacing during the monsoon season. To ensure successful establishment, seedlings should be planted with their balls of earth. Closer spacing leads to height growth and not preferred by pencil and plywood industry. Therefore, wider spacing can be adopted to have more girth and also for intercropping during the initial period of 1-2 years (Vijayaraghavan, 2014). Spacing trials have revealed that closer spacing of 1.83 m × 1.83 m gives the highest yield and the widest spacing of 3.66 m × 3.66 m the lowest; moreover the spacing appears to have a direct effect on the survival of plants (Luna, 1996). To attain optimal growth in infertile sites, fertilizers are needed. Urea and Triple Super Phosphate (TSP) are the most widely used fertilizers. According to Soerianegara and Lemmens (1993), urea at 15 gm per plant in a ring around the seedling results in a much faster growth.

Tending Operations

A. cadamba is generally considered a light-demander, requiring high light availability for seedling growth. The seedlings are highly susceptible to weeds. Therefore, after planting, the area around the young seedlings needs to be weeded, especially of climbers and plants causing shade. The commonly used weeding practices are both manual and chemical. Weeding should be done several times during the first few years after planting until the trees approach canopy closure. The interval between two successive weedings is usually 3 months during the first year, and 6 months thereafter. Pruning is usually done to produce knot-free timber. It also gives easier access to timber stands and reduces damage caused by fire. However, pruning in *A. cadamba* plantations is unnecessary as the species uses natural pruning, with dead branches falling off (Soerianegara and Lemmens, 1993).

Thinning is practiced to encourage crown development, which results in bole diameter increment, and to remove inferior trees. It should be done early and frequently, depending on the site quality and spacing, starting 2–4 years after planting. The number of thinnings required also varies depending on initial density, ranging from one to three thinnings in a rotation. Krisnawati et al. (2010) found that for plantations with a 15-year rotation and a spacing of 3 m × 2 m, three thinnings conducted at 2, 4 and 8 years of age are sufficient to obtain a high timber volume; for plantations with 3 m × 3 m spacing, thinnings should be conducted at 2, 4 and 7 years of age with a 13-year rotation. In a wider spacing (e.g. 4 m x 4 m), one thinning at 3–4 years of age works well with a rotation of 10–15 years.

Tree Protection

Among the insect pests, *Aristobia approximator* feeds on the bark, *Dihammus cervinus* bores in the stem and *Dirades adjutaria* defoliates over extensive areas. Caterpillars of the moth *Arthroschista hilaralis* (Pyralidae) and *Margaronia hilaralis* a common leaf rolling insect pest are reported to cause damage. Chemical control of *M. hilaralis* with 0.051 BHC in water is reported to be successful. In India, a

longhorn beetle, *Batocere numitor* (Coleoptera, Cerambycidae) bores into the base of the stem of unhealthy trees. The main diseases reported are on nursery seedlings and include damping-off by *Fusarium* and *Pythium* spp. The fungus *Scytalidium lignicola* is found on living branches of *A.cadamba.*

Suitable Agroforestry Systems

A. cadamba has no adverse effects on the understorey crop, if proper tree management practices are followed. For better results, the spacing adopted should be at least 5 m × 5 m/ 6 m × 6 m. Dry paddy can be cultivated up to 3 years without much difficulty. Once the trees are well grown, it is desirable to change the cropping pattern, i.e., ginger, turmeric, etc. besides vegetables, pineapple, pigeonpea and other pulses. Trees are also planted on boundaries of the fields. Hence, in farm forestry, farmers can get more yields of crops and generate higher revenue (Vijayaraghavan, 2014)

Heavy leaf shedding during autumn–spring and easy decomposition of leaves makes *A. cadamba* a suitable alternate for wheat paddy system in most parts of India. There is already a high demand for this tree from pencil, plywood and match splint industries. *A. cadamba* is also used as a shade tree in tea and coffee plantations.

***Anthocephalus cadamba* plantation**

Yield

The rotation period depends upon the production objectives. For pulpwood and matches, harvesting can start 4–5 years after planting. For wood production, felling of trees can start approximately from the age of 10 years. In Tamil Nadu, about 70-100 t/ha at a rotation of 6-7 years was realized through seed-raised plantations and it can be increased by 10-15 % by introduction of clones and through site-clone matching (Vijayaraghavan, 2014).

Utilization

The hardwood of *A. cadamba* is lightweight. The heartwood is white with a yellow tinge darkening to creamy yellow on exposure, and not clearly differentiated from sapwood (Martawijaya et al. 1989). The wood has a fine to medium texture, straight grain and low lustre and has no characteristic odour or taste. The wood density is in the range of 290 to 560 kg/sq m at 15% moisture content. It is easy to work with hand and machine tools, cuts cleanly, gives a very good surface and is easy to nail. It is very easy to preserve using either open-tank or pressure-vacuum systems. It can also be easily impregnated with synthetic resins to increase its density and compressive strength (Krisnawati et al. 2011).

The wood is extensively used for ceiling boards, light construction work, packing cases, planking, carving and turnery. It makes good veneers and plywood suitable for the manufacture of grade IV commercial plywood and tea chest plywood. It is also suitable for the manufacture of pencils, match boxes, and splints. It is reported to be suitable also for making printing and wrapping paper.

The fruit and inflorescences are reportedly edible. The fresh leaves are fed to cattle. The flowers are an important raw material in the production of “attar”, which are Indian perfumes with sandalwood base in which one of the essences is absorbed through hydro-distillation. The species is also used in reforestation and afforestation programmes. It can help improve some of the physical and chemical properties of the soil under its canopy due to its large amounts of leaf and non-leaf litter, which increase the level of soil

organic carbon, cation exchange capacity, available plant nutrients and exchangeable bases (Orwa et al. 2009).

References

Anon, 1985. Troup's Silviculture of Indian Trees. Vol VI. Controller of Publications, Delhi.

Champion, H. G. and Seth, S. K. 1968. A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi. 404.pp.

Joker, D. 2000 *Neolamarckia cadamba* (Roxb.) Bosser (*Anthocephalus chinensis* (Lam.) A. Rich. exWalp.). Seed Leaflet No. 17, September 2000. Danida Forest Seed Centre, Denmark

Krisnawati, H., Kanninen, M. and Kallio, M.H. 2010 Stand growth and management scenarios for *Anthocephalus cadamba* Miq. plantations in Indonesia. Unpublisedmanuscript. CIFOR, Bogor, Indonesia

Krisnawati, H., Kallio, M. and Kanninen, M. 2011. *Anthocephalus cadamba* Miq.: ecology, silviculture and productivity. CIFOR, Bogor, Indonesia.

Luna, R.K. 1996. Plantation trees, IBD Publisher, Dehradun, India

Martawijaya, A., Kartasujana, I., Mandang, Y.I., Prawira, S.A. and Kadir, K. 1989. Atlas kayu Indonesia Jilid II. Pusat Penelitian dan Pengembangan Hasil Hutan, Bogor, Indonesia

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009 Agroforestry tree database: a tree reference and selection guide version 4.0. International Centre for Research in Agroforestry, Nairobi, Kenya

Soerianegara, I. and Lemmens, R. H. M. J. 1993. Plant resources of Southeast Asia 5 (1): Timber trees: Major commercial timbers. Pudoc Scientific Publishers, Wageningen, Netherlands

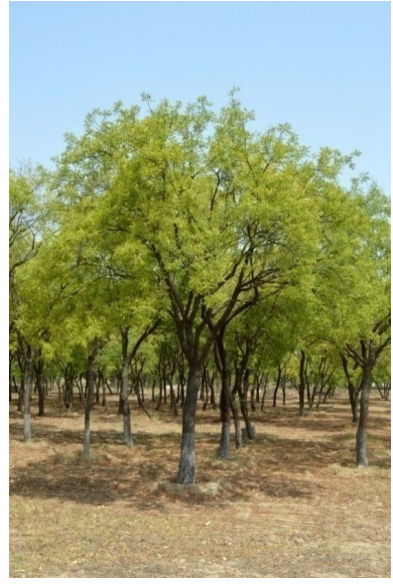
Vijayaraghavan, A. 2014. Cultivation Techniques for *Neolamarckia cadamba*. *In*: Transfer of Tree Cultivation Technologies to Krishi Vigyan Kendras (KVKs) of Tamil Nadu and Puducherry. Institute of Forest Genetics and Tree Breeding, Coimbatore, India, pp 28-32.

Chapter 6

Azadirachta indica A. Juss.

Family: Meliaceae
Common name: Neem, Indian Lilac
Trade name: Neem
Origin: India, Indonesia, Malaysia, Myanmar, Pakistan, Senegal, Sri Lanka, Thailand

Botanical Characters



***Azadirachta indica* plantation**

Azadirachta indica is a small- to medium-sized tree, usually evergreen, up to 15 m tall and 90 cm in diameter, with a round, large crown, sometimes fluted at base. Leaves alternate, crowded near the end of branches, simply pinnate, 20-40 cm long, exstipulate, light green, with 2 pairs of glands at the base, otherwise glabrous; petiole 2-7 cm long, subglabrous; rachis channelled above. Inflorescence axillary, many-flowered thyrsus, up to 30 cm long; bracts minute and caducous; flowers bisexual or male on 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 one- or two-seeded drupe, ellipsoidal, 1-2

cm long, greenish, greenish-yellow to yellow when ripe; exocarp thin, mesocarp pulpy, endocarp cartilaginous; seed ovoid or spherical; apex pointed; testa thin, composed of a shell and a kernel (sometimes two or three kernels), each about half of the seed weight (Orwa et al. 2009).

Flowers (left) and fruits of *Azadirachta indica*

Distribution

A. indica is grown from the southern tip of Kerala to the Himalayan hills in the tropical to sub-tropical and semi-arid to wet tropical regions. It has been widely cultivated in India and African countries. In India, it occurs throughout the larger parts of the country in the states of Uttar Pradesh, Bihar, West Bengal, Orissa, Delhi, Maharashtra, Gujarat, Andhra Pradesh, and Tamil Nadu; and in tropical dry deciduous and thorny forests and in the drier parts up to 1500 m.

Silvicultural Requirements

The Neem tree is noted for its drought resistance. Normally it thrives in areas with sub-arid to sub-humid conditions with an annual rainfall between 400 mm and 1200 mm. It can grow in regions with an annual rainfall below 400 mm, but in such cases it depends largely on ground water. Being a tropical/sub-tropical plant, it is found in areas with annual mean maximum temperature of 32.5 to 42.5 °C and minimum of 4 to 21 °C. Temperatures below 4 °C and frost are unfavourable. Neem is susceptible to waterlogging. It is a tree of semi-arid tropics. It grows well on a wide variety of deep or shallow soils ranging from sandy soils in Rajasthan to clayey soils in Maharashtra, but does not survive on waterlogged, highly saline or deep dry sand. Its best growth is reported from black cotton soils. Also, it thrives better than other species on dry, stony, clayey and shallow soils. It can also come up on soil, where there is hard calcareous or clay pan just below the soil surface. Its root system has an unusual ability to collect nutrients and moisture even from

highly leached sandy soils. The soil pH needed for the optimum growth is 6.2 and above. It is grown both in the plains and in the hills, ascending up to 1830 m in Kumaon.

Phenology

Neem is almost evergreen but becomes near leafless in dry localities for a short period during February-March. New leaves appear in March–April, before the old ones are shed. Flowering occurs during January–May. In Kerala flowering starts in January; in Karnataka, Tamil Nadu and Andhra Pradesh during February–March; in Central India during the first week of April; and in the sub-Himalayan area in the first week of May. Thus, flowering is progressively delayed from South to North. Fruiting also follows the same pattern: fruits ripen from June to August. The tree starts fruiting at the age of 5 years but economic yield of fruits is obtained at the age of 10-12 years. About 3300-4500 seeds weigh one kg and, on an average, a medium-sized tree produces 37-55 kg fruits (Luna, 1996).

Propagation Technology

Through Seeds

Only fruits at the yellow-green colour stage are pricked from the branches. Although Neem is a prolific seed producer, adequate seed supply is often a problem. The viability of fresh seed decreases rapidly after two weeks and improperly stored seeds have low germination rates. Therefore, collected fruits are depulped immediately. Soaking in cold water for a few hours helps in removing pulp. Storing Neem seeds for five months at 40% natural moisture content at 16 °C is possible. For shorter storage periods, the seeds are sealed in polythene bags and exposed to air once a week to keep them viable. Long-term storage of Neem seeds for more than 10 years is done at 4% moisture content and -20 °C temperature. Storage of seed in earthen pots containing wet sand (30% moisture) helps to retain 60% viability for up to three months.

As the seeds are recalcitrant, germination rate varies between 15% (stored seeds) and 85% (fresh seeds). Hence, to ensure a higher germination rate, immediate sowing of seeds in nursery is recommended. Pre-soaking for 24 hours in cold water and removal of the endocarp or making a small cut in the seed coat at the round end with a sharp knife help increase seed germination capacity. Sowing of seeds in nursery beds made up of fine river sand is done in drills 15 cm apart. Seeds are sown 2.5 cm deep at 2 to 5 cm distance in lines and lightly covered with earth to safeguard against birds and insects which often eat up radicles of the germinated seeds. Alternatively, seeds can be sown directly into pots. Germination occurs within 10-15 days. Once the hypocotyl is erect, seedlings are transplanted into containers. Seeds are sown 3 or 4 months before the scheduled planting date. Potting mix comprises 50% sandy loam, 40% river sand and 10% compost by volume. After 5 to 6 weeks, the seedlings are removed from the nursery and planted in a second nursery or in polythene bags. If polythene bags are used for transplanting, they should be filled with silt, sand, clay and farmyard manure in the ratio of 1:1:1:1.

Vegetative Propagation

Neem seedlings can also be produced vegetatively by air layering, cuttings, grafting and tissue culture (Surendran et al. 2000). But direct sowing is the most cost-effective method of propagation.

Cuttings

Neem can be successfully propagated by means of hardwood, semi-hardwood and softwood cuttings. Summer is the best season for collection of propagules.

Hardwood cuttings: About 1-2 cm diameter hardwood cuttings are collected from healthy vigorously growing branches. The terminal portion of leaves is excised and branches are made into 15-20 cm long cuttings. A 1000 ppm of IBA treatment is given as basal dip. Then the cuttings are planted in nursery beds under 50-60% shade. The per cent of rooting is low.

Semi-hardwood cuttings: These are collected from fresh growth during early morning and made into 10-15 cm long cuttings by

retaining a pair of leaves near the upper end. A 2000 ppm IBA is the best treatment which gives maximum rooting under mist. Rooting starts within 6 to 8 weeks.

Softwood cuttings: Shoots from fresh growth flush are collected in the morning and the terminal softwood portions are used for making 4-7 cm long, binodal, leafy cuttings. These cuttings are planted in vermiculture or coarse sand medium and kept in mist chamber conditions. The cuttings root within 4 weeks, and they need to be hardened before planting in the field.

Cultural Operations

Planting

The field where Neem seedlings are to be transplanted, should be properly ploughed. The seedlings are ready for transplantation when they are 4 to 6 months old (15 to 22.5 cm height). Seedlings should not be kept waiting to be transplanted for a long time because their tap root becomes very long and can get damaged when they are taken out.

Pits of dimension 30 cm × 30 cm × 30 cm should be dug at a distance of 5 m × 5 m (400 plants per hectare.). Only healthy seedlings should be chosen. Transplanting during the monsoon season increases their survival rate. Otherwise, they should be watered once every 2 or 3 days. After they have established well, they may be watered once in 7 to 10 days.

Neem can be easily raised through direct sowing, entire/polypot seedlings or root-shoot cuttings. For degraded areas direct sowing is more successful than other methods. Seeds of Neem trees can be directly sown in the fields by line sowing or broadcasting, sowing on mounds or ridges, sowing in trenches in sunken beds in circular saucers. But planting with well grown, one-year old nursery seedlings provides better survival and growth. Stump planting is also preferred in Neem.

Tending Operations

Weeding is essential to enhance the growth at both early and mature stages of the tree. Even inter-row spaces are cultivated with

annual crops to keep the field weed free in seed orchards. Two to three weedings in the first year and one in the second year are recommended for plantations raised by seedlings. The weeds and grasses around the plants must be removed within one month after plantation. The second weeding and hoeing should be done in the month of October, and plants may be irrigated as required.

About 5-6 kg green manure, 20-25 gm Edosulphan dust, 10 gm Urea, 20 gm Single Super Phosphate, 20 gm MOP (Muriate of Potash), 1-2 kg cake of Neem per plant may be used during transplantation and the following 2 years. The first mechanical thinning is usually done when the crop completes the age of 3-4 years. A second thinning may be necessary at the age of 6 years. Thinning schedule can be worked out depending upon the site quality and plant growth.

Tree Protection

For protection against harmful insects, 0.25% Malathion or 0.02% Democron should be sprayed. Tip borer (*Laspeyresia koenigiana*) and tea mosquito bug (*Heliopeltis antonii*) attack seedlings and young plants. *Pulvinaris maxima* is a scale insect now regarded as a key pest and *Heliothrips haemorrhoidalis* a potential pest of Neem. Seedlings also get severely affected by damping-off, *Rhizoctonia* leaf web blight, leaf spot and blights induced by *Colletotrichum* sp., *Alternaria* sp. and *Pseudocercospora* sp.

Suitable Agroforestry Systems

In many parts of India Neem has been found to be quite suitable as an agroforestry tree species with good economic value. In semi-arid conditions at the Indian Grassland and Fodder Research Institute, Jhansi, Neem along with other tree species increased the productivity of a silvicultural system by up to 8.5 t/ha. It has been reported that the fodder production can be increased from 0.5 t/ha to 3.6 t/ha in the arid zone of Thar Desert by growing suitable grasses and legumes along with Neem and other tree species.

The short-duration and dwarf annual oilseed as well as pulses (leguminous) crops like groundnut, mustard, chickpea, cowpea,

horse gram and soybean can be grown successfully as inter-crops for up to 4-5 years in Neem plantations. This helps generate additional income as well as facilitates maintenance of plantation during the initial 4- 5 years.

Yield

The rate of growth of Neem in plantations varies with the quality of soil. It is fairly rapid up to the age of 5 years after which it slows down. The plant attains a height of 4 m at 5 years and 10 m at 25 years. The mean annual girth increment is 2.3-3.0 cm. More rapid growth is attained under favourable conditions.

Neem bears an ovoid fruit, 2 cm × 1 cm that has a pericarp containing a resinous substance with a garlicky odour. Each seed contains one kernel. The seed kernels, which weigh 0.2 gm, constitute some 50-60% of the seed weight and 25% of the fruit. The fat content of the kernels ranges from 30 to 50%. The tree starts bearing fruit after 3-5 years and comes to full bearing at the age of 10-12 years. Fruit yield is 10-25 kg per tree per year in the initial years. A mature tree produces 30-100 kg fruit per year. It has been estimated that a 10-year-old tree can yield 5-6 cu ft of timber.

Utilization

Neem sapwood is greyish white, and the heartwood is mottled and pinkish red when first exposed. It becomes reddish brown and resembles mahogany on drying. The wood is scented, moderately hard and heavy, and medium- to coarse-textured with narrowly interlocked grain. The specific gravity of Neem wood is approximately 0.68 g/cm^3, or between 0.74 and 0.81 g/cm^3 for air-dried wood. It has a crushing strength of 420 kg/cm^2 and a coefficient of elasticity of 70 t/cm^2.

For centuries the Neem tree has provided twigs for brushing teeth, pharmaceuticals for aches and pains and pest control chemicals against insects. It is drought tolerant and helps to reduce soil erosion. It is used to produce soap, lamp oil, lubricant and lumber. It is also a good shade tree. Every part of Neem is valuable and economically important.

Neem wood is resistant to fungi and most borers. It is used for making furniture, cart axles, boards and panels, cabinets, packing cases, ornamental cuttings, ship and boat building, helms, oars, cigar boxes, carved images, toys, drums and agricultural implements. The leaves are palatable to cattle and buffaloes and constitute a traditional feed in several parts of the country. They are carminative and aid digestion; leaves are also used as mulch and manure. Tender leaves in combination with *Piper nigrum* are found to be effective in intestinal helminthiasis. Neem oil and its derivatives are mainly used in soap and toothpaste making. Oil is used to treat some chronic skin diseases and ulcers and is externally applied for rheumatism, leprosy and sprain. Warm-oil relieves ear trouble, cures dental and gum troubles and provides relief from asthma when taken with betel leaf. Oil is reported to have anti-fertility as well as anti-septic and anti-fungal properties.

References

Luna, R.K. 1996. Plantation trees. IBD Publisher, Dehradun, India

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry tree database: a tree reference and selection guide version 4.0. International Centre for Research in Agroforestry, Nairobi, Kenya

Surendran, C., Parthiban, K.T., Vanangamudi, K. and Balaji, S. 2000. Vegetative Propagation of Trees: Principles and Practices. pp 1-154, TNAU Press, Coimbatore, India

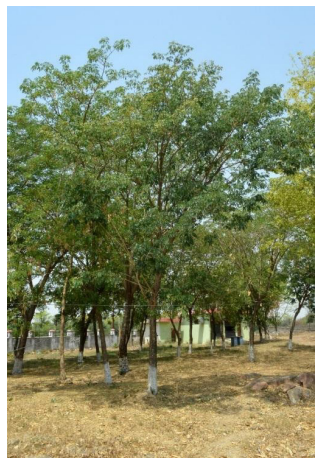
Chapter 7

Albizia lebbeck L.Benth.

Family: Mimosaceae
Common name: Kala Siris, Koko, Vagai
Trade name: Indian siris, kokko, East Indian walnut
Origin: Native to Indo-Malaya, New Guinea and Northern Australia

Botanical Characters

Albizia lebbeck is a medium- to large-size tree, of multi-stemmed widely spreading habit when grown in the open, but capable of good log form in plantations. Height growth is up to 20 m. Bark rough, grey; inner bark reddish. Leaves bipinnate, rachis 70-90 mm, rachillae 1-5 pairs, 50-70 mm. Leaflets 3-11 pairs, oblong to elliptic-oblong, asymmetrical, 15-65 mm x 5-35 mm, glabrous, entire, initially bright green and folding at night, maturing to a duller glaucous green and fixed rachis. Fully but briefly deciduous in the dry season. Inflorescence an axillary cluster of 15-40 pedicellate flowers. Peduncle up to 100 mm, pedicel 1.5-5 mm, corolla inconspicuous, free filaments numerous, 15-30 mm. Entire inflorescence, fluffy, 60 mm diameter, yellow-green with distinctive pleasant fragrance. Pod flat oblong 120-350 mm x 30-60 mm, stiff-



Fully ripened pods and trees of *Albizia lebbeck*

papery when ripe, swollen over seeds,. dehiscent. Seeds 3-12 per pod, brown, flattened, 8-10 x 6-7 mm.

Distribution

A. lebbeck is indigenous to the Indian sub-continent and to those areas of Southeast Asia with a marked dry season, such as northeastern Thailand, parts of Malaysia and in the eastern islands of Indonesia (Little, 1983; Lowry et al. 1994).

Silvicultural Characters

A. lebbeck is a deciduous tree with a wide spreading crown when grown in the open. It is a strongly light-demanding species. It grows moderately fast. The seedlings can withstand some shade, but grow best under full sunlight. It can tolerate some frost. It is frequently planted on poor sites and for erosion control, but grows best on good, well-drained loams. It performs poorly on heavy clays. It suffers greatly from browsing. It coppices well and produces root suckers if the roots are exposed.

Silvicultural Requirements

The tree can grow in regions with an annual rainfall between 500 and 2500 mm. Being a tropical/sub-tropical plant, it is found in areas with annual mean maximum temperature of 30 to 45 °C and minimum temperature of 19 to 21 °C. The species tolerates acidity, alkalinity, heavy and eroded soils, and waterlogged soils.

Phenology

A. lebbeck is hermaphroditic. In its natural habitat, flowering occurs from September to October; mature pods remain on the tree for long periods and are available during May-July.

Propagation Technology

Through Seeds

The seed should be sown directly into polypots (two seeds per polypot). The seedlings should have full light, except when shade

is necessary to protect them from hail or heavy rain. Frequent root pruning is necessary. Plantable seedlings can be obtained after 4-5 months in the nursery, from the February–March sowing; but at higher altitudes 9 to 12 months will be needed.

Through Stumps

In India raising plants as stumps has been successful. The stumps should be 8-13 mm thick at the root collar, with about 4 cm stem and 20-25 cm root. Such plants need to be raised in beds for 12-15 months before stumping.

Cultural Operations

Planting

The species prefers alluvial soils although it also comes up in clayey or moderately alkaline and saline soils, where it attains a smaller size. The planting site is cleared of undesirable vegetation by cutting and burning; 30 cm x 30 cm pits are dug before the summer season. The soil gets weathered during the hot months. In U.P., in alkaline and saline soils, larger size pits such as 60 cm x 60 cm x 90 cm, 60 cm x 60 cm x 120 cm or even 120 cm x 120 cm x 120 cm are dug and refilled with imported non-saline and non-alkaline soils. Vermiculite, gypsum and farmyard manure are also mixed in the imported soil. Since the species is vulnerable to browsing by cattle, the plantation areas need to be well protected preferably with barbed wire fencing. In wet climate as in Assam, pit digging is not necessary as stump planting in crowbar holes is fairly successful.

Tending Operations

Three weedings are carried out in the first and second year in high rainfall areas, elsewhere two in the first and second year and one in the third year, irrespective of whether the plantation is raised by direct sowing, entire transplants or stumps. Climbers and bushes likely to shade the plants are also cut. In case of direct sowing thinning of the plants is done to reduce competition. Cleaning and thinning are carried out depending upon the development of the crop and its silvicultural requirements.

Plant Protection

Five species of insects are known to attack the seeds, of which *Bruchus bilineatopygus* can cause up to 80% damage. It is a light brown, about 4.45 mm long beetle that lays oval, light yellowish eggs on young pods. The eggs hatch into small grubs, which enter fleshy pods. The damage can be seen in the form of gummy fluid oozing from the pods. The grub turns into pupa and then beetles emerge out of pods. These beetles again lay eggs on fresh pods and stored seeds. There are five generations in a year. The pest is controlled by spraying 0.05% monocrotophos on the tree in the first half of September. Mixing of Folidal 2% dust with seeds in the ratio of 1:100 is also recommended.

Young plants may be attacked by mice, rabbits, marsupials and domestic ruminants. Leaves are largely unaffected by insects, but young leaves may be attacked by larvae of the grass yellow butterfly (*Eurema hecoba*). The most serious pests are bark-feeding larvae of longicorn beetles. These do not affect small stems and have little effect on large stems, but complete girdling can cause dieback in stems in the diameter range of 40-100 mm. There is considerable variation in susceptibility of individual trees; they may be more susceptible under prolonged water stress. Recently, a psyllid, probably of the genus *Heteropsylla,* was reported as seriously affecting seedlings in India. The infestation was controlled by two applications of Nuvacron (0.05%).

Suitable Agroforestry Systems

Commonly grown as shade tree in tea plantations in Assam, *A. lebbeck* based silvipasture system is commonly practiced in plains. One of the most interesting aspects of the species is that, in addition to providing feed, it appears to enhance pasture production and quality.

Yield

In good sites *A. lebbeck* could produce 18-20 cu m of timber per hectare per year**.** Fuelwood plantations produce 5 cu m per hectare

per year. Isolated mature trees produce edible dry matter at the rate of 100-120 kg/year (Lowry, 1989). Leaf litter fall under plantation conditions was 5000 kg/ha/year. Stands of mature trees with triennial pollarding yielded 1,700 kg/ha/year of edible material. Hedgerow stands browsed by cattle twice a year yielded 2,500 kg/ha/year in a sub-tropical low-rainfall area.

Utilization

A. lebbeck is grown in some areas primarily for fodder for camels, buffaloes and cattle. The leaves are reported to contain 17-26% crude protein; a 100 kg of leaves yield 11-12 kg of digestible protein, and 37 kg of digestible carbohydrates. The pods contain saponin and are not eaten in large amounts by sheep, although cattle eat them readily. The tree's whitish flowers are fragrant and attract bees. Its nectar provides light color honey which is highly regarded by bee-keepers. The species is an excellent fuelwood tree with a calorific value of 5200 kcal/g. Sapwood is pale; heartwood is dark brown with black streaks and very decorative. It is moderately heavy and hard, strong and fairly durable, with a specific gravity of 0.5-0.6 kg/cu m. The wood seasons well, works and polishes easily, can be used for interior moulding, parquet, furniture, panelling, turnery and general construction. It is also used for making agricultural implements and mine props. The trunk yields a reddish gum that is used as an adulterant of gum arabic. The bark is used locally in India for tanning fishing nets (tannin content of 7-11%). Leaves and seeds are used to treat eye problems, and the bark to treat boils. Saponin from pods and roots has spermicidal properties.

References

Little, E. L. Jr. 1983. Common fuelwood crops. A handbook for their identification., Commune-Tech Associates, Morgantown, WV.

Lowry, J. B. 1989 Agronomy and forage quality of *Albizia lebbeck* in the semi-arid tropics. *Tropical Grasslands* 23: 84-91.

Lowry, .J.B., Prinsen, J. H. and Burrows, D.M. 1994. *Albizia lebbeck* - a promising forage tree for semi-arid regions. *In*: Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, UK, pp 75-83.

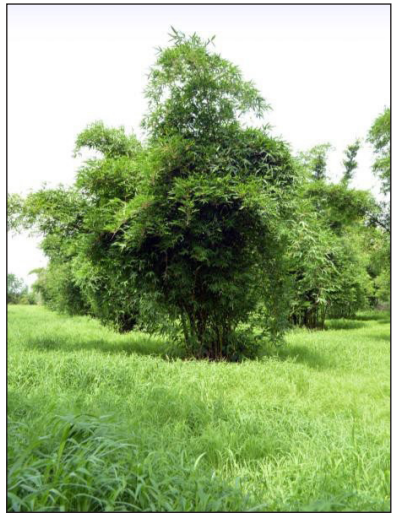
Chapter 8

Bambusa vulgaris Schrad

Family: Poaceae
Common name: Peela Bans, Bidiru, Golden Bamboo, Yellow Bamboo
Origin: Asia

Botanical Characters

Bambusa vulgaris forms moderately loose clumps and has no thorns. The culms are yellow with green stripes. The densely tufted culms grow 10–20 m high and 4–10 cm thick. Culms are basally straight or flexuose, drooping at the tips. Culm walls are slightly thick. Nodes are slightly inflated. Internodes are 20-45 cm. Several branches develop from mid-culm nodes and above. Culm leaves are deciduous with dense pubescence. Leaf blades are narrowly lanceolate.



***Bambusa vulgaris* plants**

Silvicultural Characters

B. vulgaris is a strong light demander. In the initial stages it can tolerate shade to some extent. The species does not tolerate cattle damage in the initial stages. It can withstand moderate winds, but succumbs to heavy gales in the formative years. It can withstand drought, fire and mechanical injury to some extent.

Silvicultural Requirements

The majority of bamboos thrive at 8.8 to 36° C. Rainfall is an important factor; 1020 mm seems to mark the minimum annual precipitation required.

Most bamboos are found on sandy loam to loamy clay soils, derived from river alluvium or frequently from the underlying rock. Usually bamboo prefers well-drained soils but it is also found on swampy or wet stream beds. Pure bamboo forests are found singly or in compact or open clumps, but usually bamboo forms the understorey of the evergreen, semi-evergreen, moist deciduous and dry deciduous forests of tropical areas.

Phenology

For many tropical bamboos, flowering intervals range from 40 to 80 years. Fruits ripen from February to April, or in some locations as late as June. Seeds germinate quickly, and can be preserved for 3 months to 2 years.

Propagation Technology

Through Seeds

There are two types of flowering in bamboos, gregarious and sporadic. When gregarious flowering occurs, the clumps of an entire species flower, produce seed, and then die. Although large quantities of seed are produced during gregarious flowering, they are viable only for a short period, sometimes only for a few days or months. Sporadic flowering occurs in many species, including *Yushania alpina, Dendrocalamus giganteus, Dendrocalamus strictus, Dendrocalamus hamiltonii, Bambusa tulda,* and *Guadua angustifolia.* In this type of flowering, seeds are produced but the clumps generally survive. What triggers the flowering of bamboo is not yet scientifically understood and the onset of flowering is, therefore, not predictable.

Use of Wildings

Apart from raised seedlings, wildings of bamboo from indigenous forest stands can be collected and used for raising a bamboo

plantation. Young clusters of bamboo wildings can be scooped using a spade and taken to the nursery for individual pricking into polyethylene tubes. Care should be taken to avoid disturbing intact small wildings which resemble a mass of grass in the field. Small wildings of bamboo that are pricked into tubes and kept under shade generally establish well. This method can raise many seedlings.

Vegetative Propagation

Offsets (rhizome with attached section of stem) are commonly used but their extraction is laborious and time consuming, so it is difficult to collect large quantities. During extraction, damage may also occur to the roots, buds and rhizomes of mother clumps. Offsets are bulky and difficult to transport. Only small annual planting programmes may, therefore, be possible when using offset materials. Use of culm cuttings is a viable alternative and has several advantages. Multiplication of several clumping species is possible by this method. When out-planted, vegetative materials raised from cuttings develop into clumps much faster than from offsets and even seedlings. Success rate is, however, very high with offsets.

Using Culm Cuttings

Good cuttings are obtained from 2 to 3 years old culms of healthy clumps. Double node or triple node cuttings are then prepared from the cut culms. The cuttings should be made leaving a space of 5-7 cm away from the nodes. A sharp cutting knife or panga should be used. For bamboos with thin walls the use of a saw is recommended to avoid splitting of the cut ends. The best culm cuttings are generally those that are obtained from the lower and thicker part of the culm, which has the vigour to generate roots and shoots. Successful rooting and shooting is generally harder to achieve with cuttings from the upper and thinner part of the culm. It is essential that the cuttings have either buds on the culm nodes or buds on the culm branches. All branches and leaves of the cuttings should be cut off down to the first or second branch node. The cuttings should then be buried 6 to 10 cm horizontally on a raised nursery bed prepared with a light soil and sand mixture. Buds at the nodes or branches should always be

placed on the sideways or facing upwards and never downwards. For some species, there is a higher rate of success when a section of the branch with a bud is left emerging vertically from the ground.

Using Offsets

At the onset of the rainy season and just before the emergence of new shoots, offsets can be obtained from bamboo stands by digging about 30-60 cm below ground for a rhizome of one to two years old culm. Once a rhizome is exposed, cut back the aerial culm to 60 cm in length and cut the rhizome off from the parent clump. Avoid injuring the junction of the culm and rhizome and the underground dormant buds at the base of the culm. Extracted offsets should be transported to the planting site immediately.

Using Tissue Cultured Plantlets

A very important step prior to tissue culture is the selection of elite mother plants with desired characteristics. When bamboos are micropropagated from the tissue of a mature plant, the result will be a clone of the mother plant. On the other hand, when seeds or the tissue of young plants are used as propagules, the properties of the resultant clones will not be predictable.

Cultural Operations

Planting

Site selection for various species of bamboo is important in order to enhance management, field operations and healthy growth. The selected area should not be prone to grazing or fire. The area should be selected about 2 to 3 months prior to the onset of rainfall. Bamboo prefers loamy and sandy loamy soils, but good drainage is critical since the crop cannot withstand waterlogging. Sloping land is thus preferable. For a reasonably good growth most bamboos require an annual rainfall of more than 1000 mm. Planning the field layout in north-south rows is advisable to have an even distribution of sunlight in the plantation. Planting in lines and rows makes management

of the plantation easier. In drier areas, with rainfall less than 800 mm, it has been found that mulching around seedlings encourages growth through reduced evaporation of soil water. Spot weeding rids the seedlings of competing weeds. This should be done at a radius of 60 cm around the seedlings after outplanting. Weeding should be regular or as necessary to avoid competition from weeds. The soil should be loosened at least three times during the plantation establishment year to improve aeration.

Tending

Depending on the intensity of weed growth, weeding and hoeing may have to be repeated in the second and third year. Soil should be heaped around the developing clump to allow and ease shoot production, which takes place mainly in the periphery of the clump. The very small and thin culms, and broken and over-hanging culms should be regularly removed.

Plant Protection

Diseases

Bamboo suffers from diseases caused mainly by fungi, which attack the rhizome, roots, culms, foliage, flowers and seeds. A large number of saprophytic and parasitic fungi attack the bamboo culms. Felled bamboos are damaged mostly by saprophytic, sapstain and soft rot fungi. Exposed roots are more susceptible to disease. The most important disease, causing epidemic, is the bamboo blight. This disease affected *Bambusa vulgaris* in coastal Odisha during 1985-88 causing large-scale death of full-grown clumps in village groves. It spread to Odisha from Bangladesh via West Bengal. The blight affects the young culms during or soon after the elongation process starts. The symptoms of the disease are premature death of the culm sheath, which can be easily removed, unlike the healthy ones, and partial collapse of the apical region with wet-rot patches developing on the internodes. After rotting of the internodes, a variety of insect larvae, beetles, and ants aggravate the damage. The dead areas spread rapidly in the tender culm and the apical region dies, ultimately

killing the entire clump over a period of 3-4 years. The casual agent of bamboo blight is a fungus known as *Sarocladium oryzae*, which is also a pathogen of rice. Bamboo blight can be controlled by improved cultural practices and drenching of soil by fungicides. The blighted bamboos should be removed. Light burning around the clump and provision of earth mounding to the base of the clump, before the monsoon, can improve the clump condition. Treatment of soil (drenching of bamboo clumps) with copper oxychloride and Dithane M 45 has proved effective in controlling the bamboo blight.

Insect Pests

Bamboos are prone to attack by various groups of insects: defoliators, leaf rollers, sap-suckers and shoot and culm borers. The shoot and culm borers cause more damage to bamboo clums than other groups of insects. Defoliators and leaf rollers cause serious damage during rainy season leading to foliage loss. The shoot and culm borers, belonging to Coleoptera, Lepidoptera and Diptera, mostly damage the tender culm shots. During the rainy season, when young shoots sprout, the weevils and beetles become more active and make holes in the tender culms to obtain the sap. They lay eggs below the culm-sheath. The larvae make tunnels through several internodes, perforate each node and kill the terminal shot.

Harvesting

The clumping habit of bamboo enables it to regenerate naturally after harvesting. Harvesting of bamboo is through selection of culms for cutting rather than clear felling. The planted area should normally be ready for first harvesting in about 6 to 8 years. Thereafter, cutting of mature stems can be done at intervals of 4 or more years. The cutting cycles and methods of extraction of stems from a bamboo clump entail an important management system of the entire bamboo plantation. Success or failure of crop production will, therefore, depend on how best stem extractions are carried out.

Cutting cycles and methods of cutting: After the first cutting in a plantation, subsequent selective extraction of bamboo stems should

be done at 4-year intervals. This cycle of cutting is considered suitable for a number of clumping bamboo species. Unless properly managed, clumping bamboos tend to become congested, resulting in deterioration both in quality and quantity. It is difficult to extract bamboo from congested clumps. If left untended, clumps of some species become extremely congested. In a clump, new culms are normally produced outwards, towards the periphery of the clump and the older stems are left in the centre. Harvesting of bamboo should, therefore, be from the centre and not at the sides of the clumps. This makes it necessary to maintain clumps in the shape of a horse-shoe, keeping the apex towards the side where the new culms are progressing. The open end of the horse-shoe facilitates entry inside the clump for cutting of mature stems. Alternatively, the clump can be managed by creating a cross tunnel, which divides the clump into four sections and allows full access for harvesting mature culms.

The new culms which attain an average height of over 10 m within the first few months, under suitable conditions, are soft and tend to decline unless supported by mature erect stems of earlier years. A few older stems should, therefore, always be left in the clump after cutting. Culms growing on the periphery of the clump should not be cut. Cutting should be restricted to the oldest culms in the centre of the clump. All dead and dry culms should be removed. All broken, live stems, less than 2.5 m in length, should be removed except in clumps containing less than 10 culms. In the latter case, even shorter broken culms may be retained for support of new culms. Current year's and one-year-old culms should never be cut. The number of older culms retained should not be less than the number of current year's culms. It has to be ensured that the rhizomes should not be dug out. In order to avoid congestion, all clumps should be worked. Culms should be cut at 15 to 45 cm from the ground, but not below the first prominent node above the ground. Cutting should be made with a sharp tool-bill-hook, a sharp panga or a saw so that the stump is not split. All cutting debris should be removed away from the clump.

Lopping of bamboos should be prohibited. No cutting of culms should be done during the growing season, i.e. during the

rains. Culm cutting should be done only during the dry seasons. In case of sporadic or gregarious flowering, all flowered clumps which have shed their seeds should be clear-felled. The areas under bamboo should be strictly fire-protected.

Yield

The annual yield depends on the environment as well as the species. It is generally 3-4 t/ha as an understorey in forest and 5-12 t/ ha from plantations.

Utilization

Bamboo, commonly known as a "cradle to coffin" timber, has been closely associated with life and livelihood of humans since time immemorial. Nearly 1500 uses of bamboo have been documented so far. Bamboo-made artifacts, containers, etc. are indispensable in some of the Hindu ceremonies. Some of the bamboo products are prerequisites in marriage ceremonies of many tribes and castes. Moreover, the forest produce is a source of livelihood for many, and a support for several other sectors. The agricultural sector is the largest consumer of bamboo products. Baskets, containers, ploughs, planks, winnowers and a range of other articles are used in agricultural operations. In rural households, it is used in construction of houses and fences. It even serves as food in some parts of India. Bamboo in urban homes is used in making decoration pieces, furniture or handicrafts. A major proportion of bamboo production is consumed by the paper-manufacturing industry.

Chapter 9

Casuarina equisetifolia L.

Family: Casuarinaceae
Common name: Whistling tree, Junglisaru
Trade name: Beef wood
Origin: Australia, Bangladesh, Brunei, Cambodia, Fiji, Indonesia, Malaysia, New Zealand, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Tonga, Vanuatu, Vietnam

Botanical Characters

C*asuarina equisetifolia* is an evergreen, dioecious or monoecious tree, 6-35 m tall, with a finely branched crown. Crown shape initially conical but tends to flatten with age. Trunk straight, cylindrical, usually branchless for up to 10 m, up to 100 cm in diameter, occasionally with buttresses. Bark light greyish-brown, smooth on young trunks, rough, thick, furrowed and flaking into oblong pieces on older trees. The branchlets are deciduous, drooping and needle like. Twigs deciduous, entirely green or green only at their tips. The minute, reduced, tooth like leaves are in whorls of 7-8 per node. Flowers unisexual; perianth absent, replaced by 2 bracteoles. Male flowers in a terminal, simple, elongated spike, 7-40 mm long, borne in whorls with 7-11.5 whorls/cm of spike, with single stamen. Female inflorescence on a short lateral branchlet, cylindrical, cone-shaped or globose, 10-24 mm x 9-13 mm; bracteoles more acute, more or less protruding from the surface of the cone. Infructescence a woody, cone-like structure. Fruit a grey or yellow-brown winged nut (samara). Seed solitary. *C. equisetifolia* is wind pollinated. Trees are mostly monoecious.

Flowers and fruits of *Casuarina equisetifolia*

Female cones mature about 18-20 weeks after anthesis and open shortly after this, releasing small samara. All the fruits on a tree do not mature at the same time, often presenting a problem for seed collection. In cultivation, *C. equisetifolia* hybridizes with *C. glauca* and *C. junghuhniana* (Orwa et al. 2009).

Distribution

Casuarina is an exotic tree to mainland India. It was introduced in Karwar District of Karnataka in 1668. It occurs naturally in the Andaman, Bangladesh and Burma coast. It is also found in North and North-East Australia, some Pacific islands, Indonesia, Malaysia, India and Sri Lanka. It has been introduced for firewood, beautification and other purposes to India, Pakistan, East, Central and West Africa, West Indies, Florida (USA) and the Gulf of Mexico. Casuarina is indigenous on the sandy shores and dunes along the Bengal coast, Tenasserim hills, and Andaman and Nicobar islands. It has been raised in many parts of the country as a coastal plantation, an ornamental garden tree and an inland sand dune plantation (Luna, 1996)

Silvicultural Requirements

Casuarina is a fast-growing, drought-hardy, care-free species for sites and climates as varied as coastal regions, hot humid tropics and even semi-arid regions. The tree remains unaffected even by cyclones in coastal areas. It can be grown up to an altitude of 1500 metres. It is mainly planted in areas with tropical and hot

sub-tropical climates and a mean annual temperature of 28 ^{0}C. It is a light demander requiring bright sunshine for best growth and development.

The monthly mean maximum temperature in its native area is 15–33 ^{0}C, but it is adapted to a wide range of temperatures. In its natural habitat, annual rainfall varies from 700 to 2500 mm, often with a dry season of 6-8 months. However, it has been planted successfully in areas with annual rainfall as low as 200-300 mm or as high as 5000 mm (NABARD, 2007).

The tree thrives best on loose sandy soils, laterite, rich loamy soils and some marshy places in open areas, where pH varies between 4.8 and 8.4. It prefers sandy soil with high water table during the summer. The species can also grow in saline and alkaline soils. Heavy, clayey soils and soils with poor drainage are detrimental to its growth. This may be because the activity of nitrogen-fixing bacteria in root nodules is inhibited in such soils. Good plantations can be seen on laterite soils and well drained sandy loams. Topography ranges from coastal flats to gently undulating terrains.

Phenology

Casuarina is generally evergreen. Pieces of the jointed branchlets are shed all-round the year. Flowering occurs twice a year, once from February to April and again from September to October. Fruit ripening occurs in June and again in December. Seeds are viable for about six months or so, though it is always better to use fresh seed.

Propagation Technology

Through Seeds

Casuarina is largely dioecious, that is, male and female populations occur at 56% and 42% approximately but there may be 2 to 3% bisexual plants. Well grown trees of 5 to 6 years age are selected for collection of ripe cones, before they dehisce, in June or December, by lopping the branches or beating the trees and collecting the cones

from ground, swept clean beforehand. Cones are spread out on clean floor in the sun to dry for 3 to 4 days when the winged seeds are shed, which are then separated. The cleaned seeds are dried for another 2 to 3 days. To protect the seed from ants and other insects, it is mixed with ash and stored in earthen pots, mouth sealed with cloth. It can be stored for a few months. It should preferably be sown immediately after collection.

Generally no pre-treatment is necessary for Casuarina seeds. In each bed about 250 g of seeds are evenly spread and overlaid with a thin layer of sand. The sand bed is covered with rice straw to prevent washing off of seedlings while watering. Water is provided through a rose can or a sprayer. A suitable repellent is applied along the periphery of the bed to prevent ants removing the seeds.

Seeds start germinating from the 5th day and the straw is removed on the 7th day. They are grown in the mother beds for the next 3 to 4 weeks. After 4 weeks when the seedlings attain 8-10 cm height they are transferred either to a secondary bed or polythene bags. Seedlings pricked from the primary beds are transplanted in the secondary bed at approximately 4 cm apart. Seedlings are grown in the secondary beds for 3 months to obtain a height of 30 to 45 cm and a collar diameter of 3 to 5 mm. Growing seedlings in polybags and root trainers is better than bare root seedlings especially for planting in rainfed areas. Seedlings raised in containers establish well in plantations and record vigorous growth in the first year. Polybags (size: 15 cm x 7 cm) filled with a potting mixture of sand, farm manure and soil in a ratio of 2:1:1 are suitable for raising Casuarina seedlings. Seedlings may attain plantable size within 2 months but can be maintained for another 4 to 6 months if planting is delayed.

Vegetative Propagation

Outstanding Casuarina trees can be propagated by rooting of young shoots (‘sprigs’). Such plants produce uniform superior growth in plantations. Sprigs collected from selected trees are trimmed to 8-10 cm long and washed in a 5% solution of fungicide like Bavistin. The lower portion of the shoot is treated with a rooting hormone, Indole butyric acid. The treated cuttings are placed in root trainers

containing vermiculite or treated coir pith and kept in mist chamber or propagation chambers made of polythene sheets. Rooting occurs in 15 to 20 days and the cuttings are then transplanted into polybags or root trainers and grown in the same way as seedlings.

Mini Clonal Technology

A mini clonal technology has been developed by the Forest College and Research Institute (FCRI), Mettupalayam, Tamil Nadu, India

Preparation for cuttings

Collected leaf cuttings

Immersing the cuttings in IBA

Planting the cuttings in polybags

Fig. 1. Propagation of Casuarina through mini clonal technology

for Casuarina. Under this technology, the superior clonal plants are planted in a mini clonal garden (Fig. 1) and are provided with regular irrigation and fertilization to enhance shoot multiplication. The mother plants are planted at 10 cm x 10 cm spacing and, after 30-45 days, are ready for cuttings. The newly induced shoots are separated from the plants and treated with 1500 ppm IBA (liquid formulation) and planted in 90 cc root trainers filled with decomposed coir pith. Rooting starts in 15 to 25 days. Under this method, rooting efficiency

and uniformity increases significantly which results in uniformity in establishment, growth and development of Casuarina clones.

Inoculation with Frankia

Casuarina is a nitrogen-fixing tree through a symbiotic relationship with an actinomycetes called Frankia. It is necessary to ensure infection of Frankia in Casuarina seedlings for vigorous growth as well as to increase their adaptability to planting conditions. Frankia can easily be inoculated by adding topsoil from Casuarina plantations to the mother beds. Alternatively, it can be inoculated at the time of transplanting into secondary beds or containers by treating the seedlings with nodule extract of Frankia culture. Application of bio-fertilizers like phosphobacterium and *Glomus fasciculatum* also improves the seedling quality.

Cultural Operations

Planting

The area should be cleared of all the debris and miscellaneous growth, if any. A light ploughing should be carried out before alignment. Where irrigation is available, it is recommended to plant one month before the rain and provide water once or twice a week. This will help the plants to establish well before the arrival of monsoon and grow faster than those planted during the rainy season. Land must be preferably disc ploughed twice. Pit size for planting container-raised plants (polybag or root trainer) is 30 cm x 30 cm x 30 cm. The recommended spacing for realizing full potential of genetically improved planting stock is 1.5 m x 1.5 m. Add a basal dose of 10 gm of Super Phosphate per pit before field planting of seedlings. Application of an antitermite solution (e.g. chlorophyriphos 1ml per litre of water) may be needed in red soils or where the problem has been encountered before. This may not be necessary in sandy soils in coastal areas. If no rain is received soon after field planting of seedlings, watering on alternate days would be necessary for the first two weeks. The frequency may be reduced gradually to once or twice a week depending upon local conditions.

Tending Operations

Casuality replacement should be taken up only up to one month after planting. Four weedings would need at 3, 6, 9 and 12 months or till the canopy closes, whichever is later. Two prunings should be done at 12 and 24 months. Branches are pruned flush to the stem up to one-third of the stem height to augment height increment and to obtain clean bole during an early stage (6-12 months). Casuarina needs to be irrigated every 10-15 days. It is advisable to use drip irrigation in order to effectively manage the available water and increase yield. Since the trees have nitrogen fixing root nodules, the need for nitrogen supplement is less. However, 40-50 kg/ha of nitrogen can be applied in four equal splits. Super Phosphate at 150 kg/ha and Muriate of Potash at 100 kg/ha can be applied in four to five equal splits. Fertilizer application is not necessary after planting if the land is fairly fertile. In low-nutrient soils DAP at 40 kg/ha may be applied.

Tree Protection

Major Pests

Several insect pests attack the tree (Table 1). A bark eating caterpillar causes heavy damage to trees due to the cylindrical tunnels created within the wood. Control of the pest is difficult; however, application of 1 or 2 ml of kerosene into the tunnels has been found effective. Monocrotophos at 5 ml/per tree as bark padding has also been found to be effective. Termites also cause serious damage in young plantation by destroying the root system leading to the death of young trees. This can be arrested by soil drenching with chlorpyriphos at 0.2%.

Major Diseases

Casuarina plantations are vulnerable to various diseases (Table 2). The stem canker and dieback can be controlled by the application of Bavistan at 0.01% active ingredient. Wilt caused by *Trichosporium* sp. could be managed with proper soil and water management. Severely damaged trees must be uprooted.

Table 1. Important pests and their control measures

Pest	Control measure
Bag worm	Application of endosulfan or chloripyriphos 2 ml/litre
Termite	Application of chloripyriphos 2 ml/litre
Stem borer	Inserting wire to remove feeding larvae and applying Insecticide-soaked cotton (15 ml of dichlorovos)
Bark eating caterpillar	Remove the feeding galleries and apply insecticide-soaked cotton (dichlorovos 15 ml) in bore holes
Mealy bug	Topical application of methyl dematon or dimethoate (2 ml per litre)

Table 2. Important diseases and their control measures

Disease	Control measure
Damping off	Proper drainage, seed treatment with Captan/Thiram at 4g/kg and soil drenching with carbendazim at 0.1%.
Stem canker	Spray with Mancozeb at 0.25%
Wilt	Remove the infected trees; dig trenches around the infected trees; scrap the infected portion and spray with copper oxychloride at 0.25%.
Pink disease	Remove severely affected plant parts or scrap the infected portions and apply Bordeaux paste.
Dieback	Spray with Mancozeb at 0.25% or copper oxychloride at 0.25%.

Suitable Agroforestry Systems

A NABARD-supported R&D project on "Development of Agroforestry Models for Various Agro-ecological Regions" was carried out by the Institute of Forest Genetics and Tree Breeding, Coimbatore. The study revealed the potential of Casuarina as the main species in different agroforestry models listed in Table 3 (NABARD, 2007).

Table 3. Different Casuarina-based agroforestry models

Agroforestry models	Species combination
Agri-Silviculture	Casuarina+Maize/Fodder Sorghum and Casuarina + Vegetables (Chillies/Tomatoes/Pumpkin/Groundnut)
Silvi-Horticulture	Casuarina+Mango, Casuarina+Coconut. Casuarina+Banana, Casuarina+Teak+Papaya. Casuarina+Drumstick+Hybrid Tomato. Casuarina+Tamarind+Drumstick. Casuarina+Teak+Eucalyptus+Guava
Silvipasture	Casuarina+Napier grasses
Bund Planting	Casuarina as Wind Breaks
Block Planting	Block planting of Casuarina
Line Boundary Planting	Boundary planting in single as well as double rows, Casuarina+Teak on Boundary, and Casuarina + Coconut as line planting
Homestead	Multi-storeyed Cropping System--Teak/Casuarina/ Banana/Vegetables

Casuarina and cowpea based agri-silviculture system

Casuarina and okra based agri-silviculture system

Yield

The commonly followed rotation period is 4 years with irrigation and 6 years under rainfed conditions. But the duration varies greatly in different areas and between farmers. Wood production varies greatly across locations, based on cultivation techniques adopted and age at which trees are harvested. Plantations with irrigation and fertilizer application yield 100 to 150 t/ha of air-dried wood (up to 20 cm girth) in 4 years. Under rainfed conditions, an average yield of 75 to 100 t/ha is obtained in 6 years depending on soil quality and amount of rainfall during the cultivation period. IFGTB (Institute of Forest Genetics and Tree Breeding, Coimbatore, India) supplies high quality seeds from seed orchards which can improve yield by up to 25% and superior clones by up to 50%: IFGTB CE 1, CE2, CE3, CE4, CJ9 and CJ10 (Nicodemus, 2014).

Utilization

Casuarina is a good pulpwood species. Yield and strength of the pulp are reported to be satisfactory for wrapping paper and duplex paper. It produces the best firewood in the world and high-quality charcoal. Calorific value of the wood is 5000 kcal/kg. Heartwood is also resistant to dry-wood termites. On sawn timber, the rays are

prominent on radial faces. Uses include house posts, rafters, electric poles, tool handles, oars, wagon wheels and mine props.

Since it is salt tolerant and grows in sand, *C. equisetifolia* is used to control erosion along coastlines, estuaries, riverbanks and waterways. Many areas where the species naturally occurs are susceptible to tropical cyclones or typhoons, and its general tolerance to strong winds has encouraged its use in protective planting. The abundance of highly branched twigs absorbs wind energy amazingly well. In areas with hot, dry winds the tree protects crops and animal herds.

With high productivity and properties that enhance soil fertility, *C. equisetifolia* is a promising agroforestry species for arid and semi-arid areas. With its deep taproot it can withstand cyclonic storms better than any other species and is very useful as a windbreak and for sand dune stabilization.

References

Luna, R.K. 1996. Plantation Trees. IBD Publisher, Dehradun, India.

NABARD, 2007. Casuarina. *In*: Model Bankable Projects: Forestry Wasteland. http://farmextensionmanager.com/English/Agribusiness%20oppertunities/Forestry%20sector/Casuarina.htm

Nicodemus, A. 2014. Cultivation techniques for Casuarina. *In*: Transfer of Tree Cultivation Technologies to Krishi Vigyan Kendras (KVKs) of Tamil Nadu and Puducherry. Institute of Forest Genetics and Tree Breeding, Coimbatore, India, pp 6-11.

Orwa, C., Mutua, A., Kindt, R., and Jamnadass, R. and Anthony, S. 2009 Agroforestry tree database: a tree reference and selection guide version 4.0. International Centre for Agroforestry Research, Nairobi, Kenya

Chapter 10

Ceiba pentandra (L.) Gaertn

Family: Bombacaceae
Common name: Kapok tree, Silk-cotton tree, Safed simal
Trade name: Kapok tree
Origin: Mexico, Maldives, Caribbean, Central America, Northern and Western South America, Brazil, Western Tropical Africa and Southeast Asia

Botanical Characters

Ceiba pentandra is a medium-sized to large, deciduous multipurpose tree with a characteristic appearance producing stiff horizontal branches generally in whorls of three. The clean bole height is about 12 m and the height of the tree about 25 m. The leaf is glabrous and digitate, being composed of 5, 7 or 9 leaflets. Leaves are alternate with slender green petioles. There are usually 5 leaflets in a mature form. The leaflets hang down on short stalks; short pointed at the base and apex, not toothed on edges, thin, bright to dark green above and dull green beneath. Calyx cup-shaped, with 5-10 shallow teeth. Petals 5, white to rose coloured; brown, silky, densely hairy on the outer surface; stamens 5, longer than petals, united into a column at the base. Fruit a leathery, ellipsoid,

Plantation of *Ceiba pentandra* in Bundelkhand region of Central India

pendulous capsule, 10-30 cm long, usually tapering at both ends, rarely dehiscing on the tree. White, pale yellow or grey floss originates from the inside wall of the fruit. Seed capsules split open along 5 lines. Each capsule releases 120-175 rounded black seeds embedded in a mass of grey woolly hairs. Seeds are dark brown in colour (Orwa et al. 2009).

Distribution

C. pentandra is native to India, Indonesia, and USA and is mostly cultivated in Southeast Asia. It is widely spread between 15-20°N and 15-20°S in various types of moist evergreen and deciduous forests as well as in dry forests. It mostly occurs in secondary forest as it is a pioneer species. It requires high rainfall during its vegetative development and a drier period for flowering and fruiting. It is generally found in areas where annual rainfall ranges from 750 to 3000 mm and dry periods do not exceed 4 months, with a minimum of 150-300 mm well-distributed rainfall during these periods. It has been widely introduced in the hotter part of western and southern India.

Silvicultural Requirements

Abundant rain is required during the growing season. The tree prefers a dry period from the time of flowering till the pods ripen. The rainfall range it prefers is between 750 and 3000 mm. The soil should be deep permeable, volcanic loam. Absolute maximum and minimum temperature range is 35-49 °C and -4 to 18 °C, respectively. Best-suited soil is alluvial with a considerable proportion of sand and good moisture supply. The species also survives in poorly drained sites. It is a strong light demander and drought resistant, and is fairly resistant to frost and fire. It produces root suckers and allows early coppicing. Pollarding can also be done.

Propagation Technology

Through Seeds

The seeds are easily separated from the fruit floss by shaking dehiscent fruits in a bag. Seeds may be stored up to one year in glass or plastic containers at 4 °C and 60% relative humidity. Long-term

seed storage has not proven successful, because the seed oil goes rancid. Fresh seeds have germination rates of 90–100% when pre-treated. Germination is good in sandy soil with temperatures of 20–30 °C. Mortality is high in seedlings and saplings grown in shaded locations. Young plants can be grown in a nursery and transplanted in the field when they are 4–10 months old. It is recommended, however, to sow directly on land which has been properly prepared for planting.

Vegetative Propagation

C. pentandra is easily propagated from cuttings, which should be taken from orthotropic branches. Trees raised from seeds root deeper than those raised from cuttings, but develop slower. The tree can also be propagated using one-year old stumps.

Cultural Operations

Planting

Seeds are sown in polypots (2 seeds per bag). Germination starts within 7 days and completes within 20 days. About 30 to 60 cm tall seedlings are planted in the field in August (rainy season). At other times of the year, planting should be done with irrigation. The spacing followed is 7 m x 7 m in plantations. Pit size is 30 cm^3. In areas receiving less than 1000 mm rainfall, seedlings would need to be irrigated at 10-day intervals, specially during the summer season.

Tending Operations

C. pentandra requires little attention, but the soil must be occasionally weeded and loosened. Usually, fertilizers are not applied. Pruning is not required. The tree performs best in locations where the vegetation is actively managed, particularly not allowing any climbers to establish, to maintain sunny conditions.

Tree Protection

High seedling and sapling mortality may occur in humid climates as a result of leaf spot, dieback, damping off and anthracnose diseases caused by various fungal pathogens. Tests have shown that leaf spot and anthracnose are caused by *Colletotrichum capsici*, whereas

Fusarium solani and *Lasiodiplodia theobromae are* associated with dieback of stem. The most effective fungicides for preventing these infections are Kocide (Cu-hydroxide, at 6.6 gm/l) and Aliette (Aluminum tris (ethyl phosphite), at 5 gm/l), although these fungicides retard the growth of seedlings.

Suitable Agroforestry Systems

Bund planting with a spacing of 6 m may be used, leaving the main field for agricultural crops. *C. pentandra* can also be planted as a shade tree in coffee and cocoa systems.

Yield

C. pentandra tree is usually felled above its buttresses, which may necessitate the construction of platforms. To obtain fibre, the fruits are harvested when fully ripe and, in dehiscent types, before they open. Ripeness is indicated by the fruit colour changing from green to brown and the surface becoming wrinkled. The fruits are normally harvested by knocking them off the tree. Trees normally start to bear fruit when they are 3–8 years old. A tree 70 cm in diameter above the buttresses yields, on average, 4 cu m of timber, and those 100 cm and 150 cm in diameter yield 9.3 cu m and 23 cu m, respectively.

Under optimum conditions a full-grown plantation tree may yield 330–400 fruits per year, giving 15–18 kg fibre and about 30 kg seed. A satisfactory average annual fibre yield is about 450 kg/ha, whereas about 700 kg/ha is considered very good.

Utilization

C. pentandra is in great demand for matchwood and is quite suitable for light plywood containers. It is also used for packing cases, shingles, well-curbs, brush handles, dug-outs, etc. Floss from the tree is the Silk Cotton or Indian Kapok, which is used for stuffing cushions, pillows, upholstery, packing, etc. Bark exudes a gum, known as mochras, which is of great medicinal value. Inner bark yields a good fibre suitable for cordage.

Reference

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry tree database: a tree reference and selection guide version 4.0. International Centre for Research in Agroforestry, Nairobi, Kenya

Chapter 11

Dalbergia sissoo Roxb

Family: Papilionaceae
Common name: Indian rosewood, sissoo, shisham
Trade name: East India Rose wood
Origin: Himalayan foothills in northern India. Naturalized or subspontaneous in many areas in western and central Asia

Botanical Characters

Dalbergia sisso is a medium- to large-sized deciduous tree, growing up to 30 m in height and 80 cm dbh (diameter at breast height) under favourable conditions. Crown wide spreading and thin. Bark thin, grey, longitudinally furrowed, exfoliating in narrow strips. Develops a long taproot from an early age, and numerous lateral ramifying roots. The leaves are imparipinnate; leaflets 3-5, alternate, 2.5-3.6 cm in diameter, broad ovate, acuminate, glabrescent, petiolules 3-5 mm long. Flowers 5-8 mm long, pale white to dull yellow, racemes 2.5-3.7 cm long in short axillary panicles. Pods 5-7.5 cm x 8-13 mm, narrowed at the base, indehiscent, glabrous, with 1-4 seeds. Seeds

Pods (left) and mature Shisham trees

6-8 mm x 4-5 mm, kidney shaped, thin and flat, light brown. The small bisexual flowers are borne on small branches from the leaf axis. Little is known of pollination biology and breeding system. The species appears to be insect pollinated, and trees can apparently be both self- and out-crossing to varying degrees, depending on local conditions. Leaves fall and young flower buds appear with new leaves followed by complete pod formation and maturity. Mature pods remain attached to the tree for 7-8 months and are then dispersed by wind and water.

Distribution

Shisham grows naturally and is also planted on alluvial soils. It is widely distributed on riverain beds in sub-Himalayan tract from Indus to Assam and Himalayan valleys, up to 900 m and occasionally ascending to 1500 m. It grows abundantly and forms a forest, either pure or mixed with other species on the new alluvium formed of deposits of sand, boulders etc., in the riverbeds of these regions

Silvicultural Requirements

The plant naturally occurs in sub-tropical and tropical moist and dry regions of the country, where the mean annual rainfall is 500 –4500 mm and mean annual temperature ranges from -4 to 45 ºC. The plant also survives in open sunny and low rainfall areas. *D. sissoo* grows well in a wide range of soil types, from pure sand and gravel to rich alluvial soil of riverbanks. However, growth is slow in poorly aerated sites, such as those with heavy clay soils. The pH tolerated is in the range of 5-7.7.

Silvicultural Characters

It is a moderate light demander and prone to damage by frost, does not tolerate poor drainage. It is a good coppice tree species.

Propagation Technology

Through Seeds

Shisham can be easily propagated by seed. The 1000-seed weight is 18–25 gm. When stored dry or in a cold store, seeds remain

viable for up to 1.5 years. Usually seeds are not extracted from the pods, but the pods are broken into 1-seeded pieces. Seeds have no dormancy, and germinate easily with germination percent up to 100. Pre-treatment of seeds is not necessary, but soaking in water for 12–24 hours accelerates germination. Germination of fresh seed takes 7–21 days.

Vegetative Propagation

Stump planting is very successful; it is recommended to use stumps from 0.5–2-year-old seedlings with a root length of about 25 cm and a shoot length of about 7.5 cm. In India successful methods of tissue culture have been developed, and in-vitro mass multiplication of *D. sissoo* is carried out from callus of shoot tips and shoot segments. Root suckers and root and stem cuttings can also be used for propagation.

Cultural Operations

Planting

Directly sown seeds attain 15-25 cm after the first rains, 90-120 cm after the second rains in India. For seedling transplantation, only tender plants with small taproots should be used. Root suckers transplant satisfactorily in dry climates. Planting should be done in monsoon in India. Plants are big enough by the beginning of the next season to yield stumps. Plants are pulled out and stems and roots chopped off leaving 3-5 cm of the former and 22-35 m of the latter; their lateral roots are also removed. Stumps thicker than 2.5 cm and thinner than 2 cm diameter at the collar are rejected. Where subsoil water is low or rainfall poor and uncertain, irrigation is essential. Shallow and frequent irrigation or constant flooding is harmful and induces superficial root formation. Depending upon the weather and condition of the plants, 10-15 irrigations are adequate in the first season and 4-6 in the second. Irrigation in later years is required only for supplementing subsoil water supplies.

Depending on management objectives, *D. sissoo* can be established in block or strip plantations at 1.8 m x 1.8 m to 4.0 m x

4.0 m spacings. Strip plantations are common along field boundaries, road sides and canal banks. In general, closer spacing is used when *D. sissoo* is planted in pure stands. This produces straighter trees of better timber quality.

Tending Operations

Regular weeding is necessary for several years. Pruning of young trees helps to produce clear boles. First thinning is recommended 5–6 years after planting, and subsequent thinning after 15 and 20 years to a final density of 200 stems/ha. In India rotations of 10–22 years are used for fuelwood production in irrigated plantations, and of 40 years for good-quality timber. Trees can be coppiced, although it has been observed that coppiced trees lose vigour after 2–3 rotations. On a good site at close spacing, complete canopy closure occurs within three years. The recommendation is to thin 30 to 40% of the tree stems when closure occurs. Thinning should be selective, removing any trees that are suppressed, diseased or badly formed. During the first thinning, at least 60% of the original *D. sissoo* stems must be retained. More intensive thinning will encourage branch growth on the remaining trees, decreasing their timber quality. A second thinning is recommended when the trees are 10 or 11 years old. A third thinning may be necessary if the rotation age is greater than 20 years. It should occur when half of the remaining rotation period has passed. Remove only inferior trees that are restricting the growth of neighbouring trees of superior quality. When the rotation age is 30 to 60 years, thinning may be necessary every 10 years.

Plant Protection

Fusarium solani and *Fusarium oxysporum* cause widespread damage to Shisham plantations in India, especially in localities with clayey soils and regular waterlogging. The symptoms are inward rolling of young leaves, dieback and discolouration of other leaves, and formation of red streaks on outer layers of the sapwood. *Ganoderma lucidum* causes root rot, usually in older trees, and several other fungi attack the leaves, causing leaf spot, leaf blight and powdery mildew diseases. Leaf rust fungi (*Uredo sissoo* and *Maravalia achroa*) may

be pathogenic in nurseries. Serious dieback due to diseases has also been reported. The trees are attacked by various insects such as leaf miners, defoliators and stem borers. To control these parasites it is necessary to cut the branches that have been attacked.

Suitable Agroforestry Systems

Common agroforestry systems are *D. sissoo* + wheat, and it can be a component of silvipasture system. It can also be used as a windbreak in mango, coffee and tea plantations.

***Dalbergia sisso* and wheat based agrisilviculture systems**

Yield

Irrigated plantations are reported to yield fair quantities of timber and fuelwood. Trees may attain a girth of 1.2 m in 25 years. A height of 7 m in 20 months has been reported. Based on studies of 40 natural riverine sites, it was concluded that 10-year stands yield about 10 cu m/ha, 20-year 100 cu m/ha (5 cu m/ha/yr), 30-year 210 cu m/ha (7 cu m/ha/yr), 40-year 280 cu m/ha (7 cu m/ha/yr), 50-year 370 Cu m/ha (7.5 cu m/ha/yr), and 60-year-old stands 460 cu m/ha (7.5 cu m/ha/yr).

Utilization

Young branches and foliage form excellent fodder with a dry-

matter content of 32.46% and crude protein 2.7- 24.1%. The foliage is used as emergency feed when other fodder sources are in short supply. The species is fast growing, hence suitable for firewood. Sapwood and heartwood have calorific values of 4.9 and 5.2 kcal/g, respectively. Pulp from wood is used in producing writing and printing paper. *D. sissoo* is one of the most useful timber species of India. The heartwood is very hard and close grained with a specific gravity of 0.62-0.82. It seasons well and does not warp or split; it is extremely durable and is one of the timbers least susceptible to dry-wood termites in India. Wood offers resistance to sawing and cutting but is excellent for turnery, takes a good polish and finishes to a smooth surface. It is used for high-quality furniture, cabinets, decorative veneer, marine and aircraft grade plywood, ornamental turnery, carving, engraving, tool handles and sporting goods. Its root wood is used for tobacco pipes. In village industry, *D. sissoo* is popular for making doors and windows. The pods contain 2% tannin.

Chapter 12

Eucalyptus tereticornis Sm

Family: Myrtaceae
Common name: Safeda, Mysore gum
Trade name: Eucalyptus
Origin: Australia

Botanical Characters

Eucalyptus is a fast-growing, medium-sized to tall tree attaining 20-50 m in height and up to 2 m in diameter. The tree has a deep tap root system with mycorrhizal associations which increases its ability to draw nutrients and water. The tree has a smooth silvery white stem. The leaves are leathery in texture, hang obliquely or vertically and are studded with glands containing aromatic oil. Flowers in bud are covered with a cup- like membrane, which is thrown off as a lid when the flower expands. The

Eucalyptus trees

Flowers and capsules of Eucalyptus

fruits are surrounded by a woody, cup-shaped receptacle and contain numerous minute seeds.

Distribution

In India Eucalyptus is the second most widely planted species after teak. Except in the north-eastern states, it has been planted on a large scale in Andhra Pradesh, Tamil Nadu, Punjab, Uttar Pradesh, Haryana, Maharashtra, Kerala, Karnataka and Madhya Pradesh.

Silviculture Requirements

Eucalyptus is a versatile, fast-growing and strongly coppicing tree possessing a wide range of soil and climatic adaptability. Basically a light demander, shade retards its growth. It is known for its drought hardiness. The species is also moderately salt tolerant and relatively fire resistant. It grows under a wide range of climatic/soil conditions from warm to hot, sub-humid to humid and from good to degraded soils. It is the most suitable tree species for areas which receive 250 to 600 mm annual rainfall, although it can also grow well in high-rainfall areas (about 1250 mm). The average mean annual temperature required is 10-27 ^{0}C, and the mean maximum temperature 22-42 ^{0}C. This species occurs on a variety of soil types from red or black to sandy alluvial. But it grows best on well drained fertile soils rich in organic matter, and loamy to sandy loam in texture. It can also grow well in salt-affected areas.

Phenology

Flowering takes place during July-August. Fruiting occurs during September-October.

Propagation Technology

Through Seeds

Seeds of Eucalyptus are obtained from seed orchards. A fertile mixture of soil with sand in a proportion of 1:1 must be used in germination beds. The beds are sterilized by solar radiation to

reduce weed and disease infestation. The seeds are placed in line 2-3 cm deep at 10 cm x 5 cm. The germination period for this method ranges from 4 to 5 days. The seedlings are lifted from the mother bed when they are 5 to 7 cm in height and transplanted in polybags. The seed can be directly sown in polybags or root trainers. Seedlings are ready to plant at the size of 30 cm in 4-5 months. They require periodic watering in the first stages of development.

Vegetative propagation

Through Coppice Shoots

Select a straight bole of the best growing tree. Harvest the tree about 15-20 cm above ground. Apply 1 gm of copper sulphate in 1 litre water on cut portion of stump to prevent fungual infection. The stumps start producing coppice shoots after 30 days. Single tree stumps give more than 30 nodal cuttings. These coppicing shoots, comprising 5 to 6 long internodes, are brought immediately to the nursery to be trimmed into cuttings. The trimmed cuttings are treated with a fungicide (0.1% Emission or 0.05% Bavistin), and immediately dipped in Indole Butyric Acid (4000 ppm) and planted in root trainers. Keep root trainer in polytunnels for 40 days. Transfer root trainers to hardening chamber for 20 days. The rooted cuttings are watered regularly twice a day. They are given a dose of NPK solution (1gm/l). After 20 days the rooted cuttings are transferred to open nursery for further hardening in direct sunlight. The cuttings are maintained in the nursery till they attain plantable height.

Micro-and Mini-cutting Technique

These two techniques are similar both in concept and operational procedures, differing mainly in the origin of the initial propagules. The micro-cuttings are obtained from shoot apices originating from micro-propagated plants, and the mini-cuttings from axillary sprouts of plants cloned as stem-cuttings.

The plants used to set up the micro-clonal hedge are raised from micro-propagated plants from axillary buds or conventional method. The stools are coppiced at a height of 15 cm from ground

level. The cut end should be given anti-fungal treatment (blue copper). The coppiced shoots are watered regularly.

After 15 days, juvenile shoots are ready for harvest (5 to 10 cm). Each stool would yield 5-14 juvenile shoots. The advantage

Mini hedges under mist chamber (left) and hardening sites

of juvenile shoot cutting is that shoots can be harvested every 15 days and rooted. The shoots should be green, semi-hard and healthy. Type of cuttings selected contributes a great deal to percent success of rooting.

The juvenile cuttings of 5-8 cm are treated with fungicides and their ends are treated with IBA (4000 ppm). They are then immediately placed in root trainers. The root trainers are kept in controlled/automated mist chambers (more than 80% humidity) at 25-30 °C for 20-25 days and in hardening chambers for up to 20 days and watered twice a day. They are then transferred to open conditions and kept for 5 months to harden before planting in field.

Cultural Operations

Planting

In irrigated lands, transplanting can be done anytime during the year except very hot months of May-June. For rainfed plantations,

transplanting should be done at the beginning of monsoon so that plants can take full advantage of rains for establishment and growth. Deep ploughing of the soil with disk ploughs or mould-board ploughs in both directions is recommended for preparing the field for transplanting of clonal saplings. Phosphatic and potassic fertilizers are applied following the recommendations of soil testing report. Dig irrigation channels 45 cm wide and 30 cm deep in north to south direction based on pre-determined spacing or 4 m apart (depending upon spacing to be adopted). Pit size is generally 45 cm x 45 cm x 45 cm. Pit should be dug open at least one month before planting (summer season). Each clonal Eucalyptus tree needs approximately 8-10 sq m space for its optimum growth. Square and rectangular planting is commonly followed in agroforestry plantation.

Spacings generally adopted by the growers for raising clonal Eucalyptus under agroforestry system in block plantations are: 4 m x 2 m; 3 m x 3 m; 4 m x 2.5 m; 5 m x 2 m. About 400-500 saplings per acre can be planted for timber production at 8-10 years rotation. A spacing of 3 m x 1.5 m is used for block planting at 888 saplings per acre for poles and paper pulp at 4-5 years rotation. Farmers have the option to cut 50% trees for poles and paper pulp at 4-5 years and retain the remaining 50% for timber production to be harvested at 8-10 years rotation. Plant to plant distance is kept at 2 m apart for single line or field boundary plantations. Application of 50 gm of phosphate and 250 gm of vermicompost or farmyard manure per pit has shown promising results. Soil in and around the planting pit is treated with 2 ml of Chloropyriphos in 1 litre of water to prevent damage to young seedlings by termites. Application of botanical pesticides like *Clistanthus collinus* is also useful in controlling termites.

Tending Operations

The ability of the species to compete with weeds is poor. Timely weeding is required for better growth. One hand weeding and soil working is required after ploughing. In high-rainfall areas, extensive weeding (2-3 times) must be carried out until crowns close (2-3 years). One disc ploughing during the pre-monsoon period and one

cultivator ploughing at the end of the rainy season every year keeps field free from unwanted growth. Generally, Eucalyptus is self-pruning in nature, so pruning is not recommended. Only forked and dead branches can be removed to get good quality timber. During the first year of growth debudding operations should be carried out in the lowest one-third of the stem during June-July and leader training operations should also be carried out simultaneously during the same months. While carrying out leader training all precautions must be taken and only co-leaders competing with the main leading shoot should be carefully pruned. If the apical bud sprouts and grows as leading shoot, no leader training may be required during the first year. Leader training should be carried out again during winter after completion of two season's growth as per requirements of the individual plants.

Farmers generally harvest 50% trees for pulpwood after 3-4 years and 50% for plywood after 7-8 years. Application of 100 g of NP or NPK (3:2:1) fertilizer to each tree at the time of planting ensures better establishment. For pulpwood agroforestry, 50 g of NPK Fertilizer (17:17:17) per plant is recommended during the first and the second year. Boron deficiency leads to crown dieback. The following fertilizer dosages are recommended: Urea, 50 kg per acre 3 times during year 1 and 4 times per year from second year onwards; DAP, 50 kg per acre twice a year; MOP 50 kg per acre once a year; zinc sulphate, 10 kg per acre once a year; and ferrous sulphate, 20 kg per acre twice a year (in areas with iron deficiency).

Plant Protection

Major Pests

A tiny insect, *Leptocybe invasa* (gall wasp), produces galls on leaf mid-ribs, petioles and shoot tips which adversely affect the growth of the tree. First reported in Malakampadin area in Tamil Nadu, the wasp has now spread to the neighbouring states of Kerala, Karnataka and Andhra Pradesh. According to latest reports, it has also invaded northern, western and eastern India.

Two parasitoids–*Aprostocetus* sp. and *Megastigmus* sp.–are

found to parasitize *L. invasa.* Plantations should be established with a mixture of 10 to 15 clones to broaden the genetic base. Infested plants should be removed and burnt. A mercury vapour lamp hanging over a water trough or pit containing few drops of kerosene kills the adults during emergence and checks further egg-laying. Spraying of Imidacloprid or Monocrotophos at 0.03% (1.5 ml per litre of water) in nursery during pricking of seedlings has been found beneficial in the control of this pest.

Thrips, *Frankliniella occidentalis,* cause the Little leaf disease in Eucalyptus (Rajan, 1987). Little leaf occurs on 4- to 5-year-old Eucalyptus and is graft transmissible. The causative organisms, transmitted by thrips, were identified as MLOs (Mycoplasma-Like Organisms). The damage caused on young and fresh growth of Eucalyptus shoots results in stunted growth of the plants with greatly reduced leaves, pale narrow laminae and axillary buds are stimulated to give a bushy form to the tree finally leading to distortion, wilting of foliage, mostly at the tips followed by leaf drop. This insect is mostly transmitted by wind drift and also could be transmitted *via* rooted cuttings as Eucalyptus is mostly propagated by coppice stem cuttings.

It is reported that Eriophyd mites also cause witches broom type symptoms in Eucalyptus. Termites can also cause heavy mortality. The symptoms are drooping of apical shoot followed by drying of leaves and sudden death of plant. Plant roots and underground stem are damaged by termites. Application of botanical pesticides like Kodesa (*Clistanthus collinus*) for controlling termites was introduced as an eco-friendly replacement for chemical pesticides. Chloropyriphos application in deep crowbar holes around the stem reduces the termite populations.

Major Diseases

One of the most serious diseases of Eucalyptus is canker caused by the fungus *Corticium salmonicolor* (also known as pink disease). The main pathogens responsible for the outbreak of diseases in Eucalyptus nurseries and plantations are:*Cylindrocladium* spp. and *Alternaria* spp. The fungal resistance clones short-listed are: ITC 1, 3, 6, 7, 288 and 316.

Harvesting and Yield

Generally, the rotation age for pulpwood production is 4 years and for plywood 6-8 years. The expected yield is up to 60-70 t/ha in 6-year rotations. The mean annual increment of the species is 20-60 cu m/ha/year.

Suitable Agroforestry Systems

In agri-silviculture system a wide range of crops can be grown when the spacing is 5 m x 2 m which supports intercropping up to 3 years. For block plantation the distance between the trees should be 3 m and, within rows, 1.5 m, which will hold 2222 plants per

Eucalyptus+cotton based paired agroforestry system in Andhra Pradesh

Boundary raising of Eucalyptus in Punjab

hectare and allow raising of intercrops in the first 2 years in a cycle of 4 years rotation. Intercrops such as chilli, cotton, tobacco, black gram, green gram are widely grown with Eucalyptus during the initial years.

An experiment was initiated at ICAR-CAFRI, Jhansi, in 2003 to assess the production potential of intercrops (black gram and wheat) with various clones of Eucalyptus planted at 5 m x 4 m and 10 m x 2 m spacing under boundary plantation. The grain yield of black gram was 1.0 to 1.25 t/ha during the first and second year, but it dropped to 0.16 to 0.18 t/ha after the sixth year. In case of wheat, the grain yield was 2.17 to 2.56 t/ha during the initial years, but it also dropped to 0.78 to 0.83 t/ha after the sixth year.

Utilization

E. tereticornis has strong, hard and durable heartwood, with a density of about 1100 kg cu m. It is used for construction in heavy engineering, such as for railway sleepers. The leaves are used in the production of Eucalyptus oil. In rural areas, the lops and tops are used as fuel. The calorific value of a 4-year Eucalyptus is about 19-20 MJ/kg. Green saw wood is used for boxes, pallets, bins, plank mouldings and scaffolds; the dried one is used as raw material for manufacture, moldings, and carpentry. Wood is used to extract veeners in the preparation of plywood. Eucalyptus gives good charcoal. Its poles are good for transmission purposes and are also used in construction of dwelling houses, work sheds and in mines. One of the most important uses of Eucalyptus wood is in the paper and pulp industry. Leaf extracts of the species have pesticide properties and can be promoted as a bio-pesticide. The wood and bark of the tree have a tannin content of 6-12% and 3-15%, respectively, though not used as a commercial source of tannin. Eucalyptus species are rich in nectar and pollen. It is an ornamental tree suitable for parks and avenue plantations.

Reference

Rajan, B.K.C. 1987. Versatile Eucalyptus. Diana Publishers, Bangalore, India. pp.164-172.

Chapter 13

Gliricidia sepium Jacq

Family: Fabaceae **Sub-family: Faboideae**
Common name: Mexican lilac, Mother of Cocoa
Trade name: Gliricidia
Origin: Mexico

Botanical Characters

Gliricidia sepium is a medium-sized tree. It can grow up to a height of 10 to 12 metres. The bark is smooth, whitish gray to deep red-brown. It has composite leaves, about 30 cm long. Each leaf is composed of leaflets that are about 2 to 7 cm long and 1 to 3 cm wide. The flowers have a bright pink to lilac colour that is tinged with white. A pale yellow spot is usually present at the flower's base. Fruit is a pod which is about 10 to 15 cm in length. It is green when unripe and becomes yellow-brown when mature. The pod produces 4 to 10 round brown seeds.

Flowers of *Gliricidia sepium*

Distribution

Native distribution of *G. sepium* is up to an altitude of 1600 m from Mexico through Central America to northern South America. It was introduced into Sri Lanka in the 1700s to shade tea plantations, although the Sri Lankan material came from Trinidad where it is not native. In India, except in Jammu & Kashmir, Himachal Pradesh and Sikkim, this tree is present everywhere.

Phenology

Flowering and fruiting take place during the dry season, when the tree has shed its leaves. Flowers are insect-pollinated and pods ripen 40-55 days after flowering. Seeds are mature when pods turn yellow-brown. Fruiting is relatively uniform with about 20 days from first to last seed dispersal. In more humid zones, shoot growth tends to be continuous and the evergreen tree flowers only sporadically on the basal parts of twigs from which the leaves have dropped. In the native range, *G. sepium* flowers during the early dry season between January and March, and pods ripen 35-60 days later in March-May. Leaves flush as seeds are shed, usually about one month prior to the first rain.

Silvicultural Requirements

Mean annual temperatures across the native range of *G. sepium* vary considerably, from 21 to 29 ºC. Leaves abscise when night temperatures fall below 15 ºC. It does not tolerate medium to heavy shade. It is drought tolerant and adapted to an annual rainfall regime of 650-3500 mm. It is largely deciduous where dry seasons are moderate to severe, but evergreen where there is sufficient moisture throughout the year. In its native range, it is often found on highly eroded soils of volcanic origin with a pH of 4.5-6.2, as well as on sands, heavy clays and slightly alkaline, calcareous limestone soils. It does not grow well on wet or waterlogged soils.

Silvicultural Characters

G. sepium is largely deciduous during the dry season. In areas where sufficient moisture prevails, however, the tree is evergreen. It will not, however, tolerate frosts which partly explains its absence above 1200 m in the native range. It can be managed as a coppice in areas with light frost, by cutting new growth before frosts occur. It is highly drought resistant.

Propagation Technology

Through Seeds

Seeds are soaked in water for 8-10 hr, preferably overnight. The

soaked seeds are sown in small polythene bags filled with a mixture of red soil, sand, and farmyard manure (1:1:1) and watered regularly. Generally, 3-to-4-month old seedlings can be planted on bunds in the rainy season. Seed propagation method is more convenient for establishing a large number of plants.

Vegetative Propagation

G. sepium can be propagated through stem cuttings. These should be from brownish green mature branches and should measure 2-6 cm in diameter and 30-100 cm in length. The stem cutting is normally cut obliquely at both ends, discarding the younger tips and the base is inserted 20-50 cm into the soil. The cuttings should be planted on bunds in the rainy season immediately after they are cut from the stems. Plants grow quickly from the cuttings. Propagation from stakes is simple but suitable mainly for situations where only a few trees are to be established. For hedges, cuttings are planted closely at 50 cm spacing. The hedges can be periodically pruned to provide fodder, green manure, firewood, or stakes for new fences.

Cultural Operations

Seedlings establish rapidly, generally reaching a height of 3 m before flowering at 6-8 months of age. Trees can also be established rapidly from cuttings, using stakes of 5-6 months of age, 1.5 m long and with a diameter of 3.5-4.0 cm. If the moisture is adequate, foliage will appear in four weeks.

Planting

Various planting patterns can be used, e.g. double rows or triangular. Plant populations range from 4,000 to 10,000 trees/ha. For live fences, use stakes 1.5-2.5 m long with diameters of 5-10 cm, planted 1.5-5.0 m apart to 20 cm depth. For densely planted protein banks, use stakes 50 cm long and six months of age. Very high densities are used in small protein banks. The direction of planting should be east to west to maximize sunlight interception.

Tending

The hedges can be periodically pruned to control shading. As green manure, 15 t/ha/year of leaf biomass can provide the equivalent of 40 kg/ha/year N to companion crops and pastures. The optimum frequency of lopping for leaf production depends on the local climate; trees can be lopped more frequently in the wet than in the dry season. In general, total annual biomass yield increases with less frequent cutting, but as this also increases the wood:leaf ratio the effect of cutting interval on leaf yield is less pronounced. For *G. sepium* grown in the humid tropics and used only for forage, a cutting interval of 6-12 weeks is usually recommended.

Tree Protection

Although widely grown throughout the tropics, *G. sepium* has apparently remained free of serious diseases. *Cercosporidium gliricidiasis*, chocolate or brown leaf spot, is widely recorded on *G. sepium* throughout Central and South America, the Caribbean Africa, Southeast Asia and the Pacific. Under humid conditions, it causes defoliation.

In some areas, *G. sepium* is infested with an aphid (*Aphis craccivora*) particularly at the onset of the rains, which causes blackening of the leaf surface and in severe cases death of the leaf primordia and shedding of young leaves (Nitis et al. 1989). Evaluation of 16 provenances of *G. sepium* showed that three provenances (G14, G17 and N14) were quite resistant to aphid infestation (Nitis et al. 1991).

Suitable Agroforestry Systems

Gliricidia–maize simultaneous intercropping agroforestry system has been prevalent. In addition, the species is used as live fences, to stabilise soils and prevent erosion, and to shade plantation crops. It is also used to provide shade in cocoa plantation.

Yield

One year after planting, harvesting can be started by lopping the

***Gliricidia sepium* agroforestry system**

plants at 75 cm to 1 m above the ground. For good management, plants should be pruned at appropriate time. Pruning should be done at least thrice during the year, i.e. in June (before sowing of the rainy season crop), in November (before sowing of the post-rainy season crop), and in March (before sowing of the summer crop). The lopped twigs are converted into smaller pieces and mixed into soil before crop planting. *G. sepium* annual leaf dry matter production generally ranges from about 2 t/ha/yr (Wong and Sharudin, 1986) to 20 t/ha/yr (Sriskandarajah, 1987).

Utilization

The tree is used in many tropical and sub-tropical countries for various purposes such as live fencing, fodder, coffee shade, firewood, green manure and rat poison. Live fences can be grown from 1.5 m to 2.0 m stakes in just a month. It can be intercropped with maize. Its effect is that of a potent fertilizer. It is also used for its medicinal and insect repellent properties. Farmers in Latin America often wash their livestock with a paste made of crushed *G. sepium* leaves to ward off torsalos. In the Philippines, the extract obtained from

its leaves is used to remove external parasites. This species may be planted to reduce topsoil erosion in the initial stages of reforesting denuded areas, an intermediate step to be taken before introducing species that take longer to grow. It fixes nitrogen in the soil, so it boosts crop yields significantly without chemical fertilizers.

References

Nitis, I.M., Lana, K., Suarna, M., Sukanten, W., Putra, S. and Arga, W. 1989. Three strata forage system for cattle feeds and feeding in dry-land farming area in Bali. Final report to IDRC, Canada. 252 pp.

Nitis, I.M., Lana, K., Suarna, M., Puger, A.W., Sukanten, W. and Putra, S. 1991. Farm level seed production of a top performing *Gliricidia sepium* in dry-land farming area in Bali, Indonesia. Technical Report prepared for FAO, Rome. 36 pp.

Sriskandarajah. 1987. Forage yield from *Gliricidia sepium* in Papua New Guinea. Nitrogen Fixing Tree Research Reports, No. 5, pp 49-50.

Wong, C.C. and Sharudin, M.A.M. 1986. Forage productivity of three forage shrubs in Bali, Malaysia. MARDI Research Bulletin, 14 (2), pp. 178-188.

Chapter 14

Gmelina arborea Roxb

Family: Verbenaceae
Common name: Hindi--Gomari, Gumhar, Gambhar, Sewan, Kambhari. English--White teak, Beechwood, Kashmir Tree, Goomar Teak, Gmelina
Trade name: Gumhar, White teak
Origin: Bangladesh, Cambodia, China, India, Japan, Laos, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam

Botanical Characters

Gmelina arborea is one of the fast growing indigenous multipurpose tree species which produces one of the best quality timbers in

***Gmelina arborea* trees**

India. It is a medium- to large-sized deciduous tree of up to 40 m height. The tree form is fair to good, with 6–9 m of branchless, often crooked trunk and a large, low-branched crown. It has a smooth whitish grey (ashy), corky bark, warty with lenticular tubercles exfoliating in regular patches when old. Leaves simple, opposite, ovate-deltoid, entire, coriaceous, densely tomentose below, 3-nerved from the base, acuminate at apex, cordate at base. Inflorescence is axillary or terminal panicles. Flowers brownish yellow; calyx cup-shaped, 5-toothed, teeth very small or obsolete, tomentose externally; corolla tubular, 2-lipped, ventricose, tomentose externally; stamens 4, included in the corolla tube.

Distribution

The species occurs in a variety of forest habitats, including tropical semi-evergreen, submontane, very moist teak forests, deciduous, sal and dry teak forests. It occurs naturally from 58 to 30°N latitude between 50 and 1300 m elevation in areas with distinct dry seasons. These include Bangladesh, Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, and Vietnam. In India, it is found in eastern sub-Himalayan tract, Indo-Gangetic plains, Aravali Hills, central India, western Peninsula and western Himalayas. It grows well in eastern sub-Himalayan belt but extends into mixed-deciduous forests of central India and sal forests of Uttar Pradesh, Bihar and Orissa, occasionally in wet evergreen forests of the Western Ghats. In the north-west Himalayas it ascends to 1000 m in valleys and over ridges (Gupta, 1993).

Silvicultural Requirements

G. arborea is a strong light-demanding and drought-resistant species with fairly good fire tolerance. It can adapt well to a wide range of soil and climatic conditions. It is a hardy plant and can be grown in both tropical and sub-tropical conditions. It grows very well in red sandy loam soil with a pH of 5 to 8 and a high soil depth, at an elevation of 0-1200 m. It likes humid climate with the optimum temperature range from 20 to 38^0C. The annual rainfall requirement is 750-4500 mm. It grows very well in high-sunshine, low-shade areas.

Phenology

In *G. arborea,* flower panicles appear during February when trees are leafless and continue until April, by which time the trees start bearing young green leaves. Old leaves fall during January-February and new ones appear during March-April (Troup, 1921). The fruits develop rapidly and ripen during May-June.

Propagation Technology

G. arborea is normally propagated through seeds. There are 700-1400 seeds in one kilogram (Evans, 1982). The species can also be propagated by stumps.

Through Seeds

Mature fruits fallen to the ground are collected and depulped for better germination. The seeds are air dried for 5-7 days. They can be stored with or without a fungicide dressing, and with 7-8% moisture content, at 7–8 °C. Seeds stored at room temperature remain viable only for 2–3 months.

Fresh season seeds are collected and sown in well drained raised beds (12 m x 1.2 m) at a spacing of 2 cm between the seeds and 5 cm between the rows. The depth of sowing is normally 1 to 2.5 cm. The beds should be watered twice a day. Seeds usually germinate in 7–21 days. The germination is epigeous with the radicle emerging first and the cotyledons shortly thereafter. About one kilogram of seed is sufficient for a standard nursery bed (KFRI, 2002). Germination percentage varies from 60 to 85. The seeds can be directly dibbled in polybags. They have no dormancy, and do not require any pre-treatment. However, soaking in cold water for 24-48 hours before sowing is recommended.

Stump Planting

For stump planting, 90 seeds per square meter should be sown. Seedlings are usually ready for stump preparation in 7–8 months and should have a root collar diameter of at least 2.5 cm. The stem and roots of seedlings should be pruned back to 5 cm and 20 cm, respectively. Stump planting is not widely practiced due to high

mortality. However, in Assam and West Bengal, stump planting is considered a better technique to achieve faster growth and cleaner boles.

Cultural Operations

Planting

Pits of 45 cm x 45 cm x 45 cm are dug in May and kept open for 15 days. They are then filled with standard potting media (2:1:1 soil:FYM:sand). Monsoon planting (June-Aug) is ideal as the seedlings get properly established in field conditions. The right age of seedlings suitable for planting is 6-7 months.

Square and rectangular planting of *G. arborea* is preferred in agroforestry (6 m x 6 m, 4 m x 4 m, 4.5 m x 4.5 m spacing). For the production of sawn wood, planting is done at 3 m x 3 m spacing, whereas for producing raw material for the pulp and paper industry, planting is done at 1.2 m x 1.2 m or 1.8 m x 1.8m.

Tending Operations

At least 3-4 weedings should be done during establishment period for better growth and development. Herbicide may be sprayed in case of heavy weed infestation. Pruning is done by removing axillary buds to a height of 4 m or higher because it has heavy branching habit. Pruning in 2–3 years plantations resulted in increased diameter and height. Generally, *G. arborea* is lopped during March-May in North-East India. Thinning is an important practice to enhance the production of sawn logs. It begins at 4-5 years of age for the wood used for pulp production. The alternative trees in the row should also be thinned, to avoid competition for nutrients and maximize growth.

Tree Protection

Pests and Diseases

Insect pests that are common in *G. arborea* plantations within the natural distribution area include stem borers *Dihammus cervinus*;

leaf defoliator larvae of *Calopepla leayana,* nymphs and adults of *Tingis beesoni*; and shoot cutter larvae of *Alcidodes ludificator*. The larvae of *Calopepla leayana* were found feeding on the leaves of seedlings in the nursery, destroying about 10% of them. *Tingis beesoni* causes serious damage to *Gmelina arborea* saplings (Nair, 2001).

Collar rot and seedling blight caused by *Sclerotium rolfsii* are the major diseases recorded in nursery stage. These can be controlled by the application of Bavistin (0.01% a.i.) at weekly interval and by reducing the water regime of the nursery.

Pests of teak find *G. arborea* an alternative host and, hence, it is not generally planted with teak, but in mixed plantation with such species as *Dipterocarpus, Hopea, Palaquium*, etc. (Gupta, 1993).

Suitable Agroforestry Systems

G. arborea is grown as an agroforestry tree in coffee and cocoa plantations to protect the young plantations. Rice, maize, beans, black gram, cowpea, cassava, peanuts etc. are grown along with this species as intercrops.

***Gmelina arborea*+mango agroforestry system**

***Gmelina arborea*+guava agroforestry system**

Growing *G. arborea* in agroforestry models is a commercial practice in Tamil Nadu. Some of the common models are Gmelina+Groundnut, Gmelina+Watermelon, Gmelina+Pulses, Gmelina+Maize, Gmelina+Banana. Multi-tier cropping system also has been followed in Pudukkottai district of Tamil Nadu, for example, Coconut+Gmelina+Banana+Pepper (pepper is trained on the Gmelina trees).

Yield

Based on the purpose, plantation-grown trees can be harvested between 8 and 15 years. The growth of the species is remarkably fast and on good sites the tree can reach 20 m height in 5 years. The tree attains more than 30 m height with about 60 cm dbh at maturity. Form of the tree is fair to good, with 6–9 m of clear bole.

G. arborea trees are harvested for pulp and firewood after 4–5 years of planting, and 10–12 years for log production. Under a good management regime each tree yields about 1.5 to 2 tonnes, so the per hectare yield could be in the range of 250–300 tonnes.

Utilization

The wood accepts nails, paint and stain well, and because of its smooth grain and light colour, it is referred to as ‘White Teak’ in

many locations. It has moderately low density (380–430 kg/cu m) when harvested at approximately 8 years of age in most locations. Its calorific value is about 4400-4800 kcal/kg. Wood has relatively good uniformity, stability and light colour which make it a suitable raw material for a number of products that include pulp, paper, medium density fibre board, laminated veneer lumber, wood cement composites, particle board, furniture, furniture interiors, plywood interiors, finger jointed lumber, door panelling, pallets, pencils, and match sticks. It is also used for making quality toys and picture frames.

References

Evans, J. 1982. Plantation forestry in the tropics. Clarendon Press, Oxford, UK. 472 pp.

Gupta, R. K.1993. Multipurpose trees for Agroforestry and Wasteland Utilization. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. 557 pp.

KFRI (Kerala Forest Research Institute). 2002. Plantation Technology for Nine Indigenous Tree Species of Kerala. *KFRI Research Report 231.*

Nair, K.S.S. 2001. Pest outbreaks in tropical forest plantations. Is there a greater risk for exotic tree species? Center for International Forestry Research (CIFOR), Jakarta, Indonesia
http://www.cifor.cgiar.org/publications/pdf_files/Books/Nair.pdf

Troup, R. S. 1921. The Silviculture of Indian Trees. Clarendon Press, Oxford, Vols 1-3.

Chapter 15

Grewia optiva J. R. Drumm. ex Burret

Family: Tiliaceae
Common name: Dhaman, Bhimal
Trade name: Dhaman/Bhimal
Origin: India

Botanical Characters

Grewia optiva is an important and popular agroforestry tree found near agriculture fields in the hills. It occurs naturally in the field bunds and is conserved by the villagers for its multipurpose utility. It is considered as a family tree of inhabitants. A full grown tree is moderate sized with spreading crown, reaching a height up to 12

***Grewia optiva* trees in an agroforestry system**

Fruits of *Grewia optiva*

m with a clear bole of 3-4 m and a girth of about 80 cm. Leaves are ovate and lanceolate, acuminate, base rounded with prominent nerves, margin serrate, stallately hairy on both surfaces. Flowers 1-8, together; peduncle solitary, leaf opposed or exceptionally a few axillary; tomentose, 0.8-1.8 cm long. Fruit is a drupe.

Distribution

The genus Grewia belongs to the family Tiliaceae composed of about 150 species forming an important economical complex, distributed in tropical and sub-tropical regions in Asia, Australia and Africa. *G. optiva* is distributed from the foothills of the Western Himalayas from Jammu & Kashmir to Nepal up to 2000 m elevation. It is not a common forest tree and is generally grown on field boundaries or terraces raised by the hill farmers.

Silviculture Requirements and Characters

It is a tree of sub-tropical climate. In its natural habitat, the maximum shade temperature seldom exceeds 38 ^{o}C and the minimum rarely drops below -2 ^{o}C. It grows on a variety of soils. Sandy loam soil with adequate moisture supply supports good growth.

G. optiva is a strong light demander. It can withstand heavy lopping or pollarding. It is a good coppice tree susceptible to fire and browsing. Seedlings get suppressed by dense weed growth; young seedlings dieback due to severe frost. Often cultivated in boundaries, retaining and break walls of fields in hills, it can grow

on light (sandy), medium (loamy) and heavy (clay) soils. Suitable pH: acid, neutral and basic (alkaline) soils. It prefers moist soil.

Phenology

The leaf-fall begins during March-April and the new flushes of leaves appear during April-May. Flowering occurs during April-May and the fruiting during June-July. The fruit starts ripening during October-November.

Propagation Technology

Through Seeds

Fruits of *G. optiva* are drupe type and very hard seed coats reduce natural regeneration. The fleshy fruits are rubbed and washed in water to separate out the seeds. Each fruit contains 2-4 seeds and there are about 12,000 to 15,000 seeds per kg. The seeds have a hard testa and can be stored well for at least a year without any serious drop in viability. Several seed treatments are available to improve germination in nursery. Hot water treatment is recommended for successful seed germination. The water is allowed to heat up to the boiling point, i.e. 100 °C without seeds, and then to cool down for up to 5 min. Seeds are then dipped. The seeds are allowed to soak overnight at room temperature. They are then spread on gunny bags and water is allowed to drain-off. The seeds are kept under shade for at least 1-2 hours before sowing.

Seeds are sown in seedbeds or polybags. Raised beds are not suitable because seed requires moisture for germination. The seeds are dibbled in line made on bed at the depth of 2-3 cm and 15-20 cm apart in February to March. Watering is done twice till germination is over. Healthy seeds start germinating within 15-25 days and attain 15-20 cm height in 40 days. About 65 to 80% seed germination is achieved within 15 days of sowing, resulting in a uniform stock for planting. Sowing in late March results in poor, prolonged and scattered germination and a heterogeneous stock. In polybags,

potting mixture of soil:FYM:sand at the rate of 1:1:1 should be used and 3-4 seeds sown at 3 cm depth. One-year seedlings in polybags can attain a height of 120-140 cm.

Vegetative Propagation

For stump planting, seedlings may be spaced about 10 cm apart in lines. Left over seedlings may be maintained in a nursery for next year. About 6- to 8-month old seedlings of 30-40 cm with pencil-size thickness should be selected for root and shoot planting. *G. optiva* can be successfully propagated by cuttings, under intermittent mist. Soaking the cuttings base for 20 hr in 100 mg/litre IAA gave a maximum rooting of 77.5% in June. The technique is used for mass multiplication of cuttings for plantation and seed orchard establishment. Disease and pest-free cuttings of 1- to 2-year-old seedling with a length of 18-20 cm and a basal diameter of 1 cm can be treated with IBA (250 mg/l) and NAA (500 mg/l) during winter which gives good rooting. Preference should be given to juvenile cuttings (Swamy et al. 2002). *G. optiva* can also be propagated by air layering.

Tending Operation

In agricultural fields, seedlings are preferably planted on bunds. The stones, boulders or any other hard materials are removed to promote tree growth. Preparations for planting should start in April-May. Planting is done at the onset of monsoon. Seedlings should be uprooted with ball of earth and wrapped in moist gunny bags. Planting is done in 45 cu cm pits at a spacing of 3 m x 3 m for block planting and 4 to 5 m for single-row planting along the field bunds. The pits can be dug in summer and kept open for 15-20 days for aeration. Application of FYM at the rate of 5 kg/pit, chlorpyrifos 5 g per pit mixed with soil is recommended for obtaining better height and diameter. In monsoon, one-year-old healthy seedlings of 100-120 cm height should be planted in the middle portion of pits without disturbing the ball of the earth. The seedling are firmed with supporting soil around the plant.

Saplings of *G. optiva* are sensitive to frost injury which can cause 20-25% mortality in the plantation. For the protection against

frost, regular watering and smoking the area in January-February is recommended. The thatching of the plants with stovers by erecting small tree guards also reduces the chances of frost injury. Manures applied during monsoon promote faster growth of saplings. Application of Compost 1 kg, 50 gm urea and 50 gm potash every year helps to increase height and diameter of trees. Irrigation is applied during summer to reduce morality and moisture stress. The species is very sensitive to heavy weed infestation, so weeding must be done twice a year.

Trees are heavily lopped during winter when green fodder is scarce. Cutting management is very important for trees growing along the cultivated fields. The trees shed leaves during March-April but local inhabitants harvest them in a manner that the greenery remains till end of March. The branches are lopped and leaves are fed to cattle. Since this is a lean period of fodder availability, only milking cattle are given the leaves, which are highly rich in protein and other nutrients, and do not contain any tannin.

CSWRTI (Central Soil and Water Conservation Research and Training Institute) recommended that 5-year old trees may be lopped 50% during December-January. The main shoot should be allowed to grow up to 6-7 years age, after which it can be headed back to induce lateral shoots. Also, for sustainable fodder supply from the trees, 75% lopping may be possible.

Pollarding at 2 m height can be done in December after 4 years of planting when other green forage is scarce in hills. Bisht et al. (2006) reported that during the initial 3 years, coppicing gave the highest green fodder yield (11.9, 14.7 and 16.8 kg/tree). But, from the fourth year onwards, pollarding at 2 m height leaving main shoot intact gave the highest green fodder.

Tree Protection

Protection of seedlings against defoliators with the application of insecticides is necessary. Larvae of *Diacrisia* spp. and *Chasmina tibialis* defoliate the tree while the larvae of family Cerambycidae bore into the dry and dead wood. The plantation areas need to be protected against browsing by cattle and also against fire.

Suitable Agroforestry Systems

***Grewia optiva*+maize agroforestry system**

***Grewia optiva* trees in an agroforestry system**

Utilization

The calorific value of the *G. optiva* tree is 4920 kcal/kg, which makes it a very good fuelwood tree and an alternative source of energy. It also provides fibre and edible fruits, and is used medicinally. Villagers extract the fibre by retting process. Branches of the tree

are cut during winter and dipped in water for a month. The soaked branches are beaten and fibre is extracted. Extracted fibre is used for making ropes. The leaves are used as fodder. The bark extract is used as hair wash by some women.

References

Bisht, J. K., Srivastava, A.K. and Gupta, H.S.. 2006. Management of bhimal (*Grewia optiva*) planted on terraced field bunds in North Western Himalayas. *Indian Journal of Agricultural Sciences* 76(7):438-440.

Swamy, S.L., Puri, S. and Singh, A.K. 2002. Effect of auxins (IBA and NAA) and season on rooting of juvenile and mature hardwood cuttings of *Robinia pseudoacacia* and *Grewia optiva*. *New Forests* 23 (2) : 143-157.

Chapter 16

Hardwickia binata Roxb

Family: Fabaceae
Common name: Anjan
Trade name: Indian Blackwood
Origin: Tropical South and Southeast Asia

Botanical Characters

Hardwickia binata is a moderate- to large-sized tree, up to 24-30 m tall, girth 1.8-3.0 m with a clean cylindrical bole up to 12-15 m; graceful, drooping slender branches; crown conical in early life, becoming broader later. Leaves are small, 2-6 cm long x 2-3 cm wide, alternate, pinnate, almost kidney shaped and greyish-green. Flowers are small, pale yellowish-green in axillary and terminal lax panicled racemes. The pods are flat, 5-7.6 cm x 1-1.5 cm, oblong lanceolate, coriaceous, narrowed at both ends, with parallel longitudinal veins, containing one seed near the apex.

***Hardwickia binata* trees**

The seed is exalbuminous, flat, averaging in sub-reniform, pointed at one end and rounded at the other, about 2 cm long and 0.75 cm wide, straight to slightly bended, pointed at one end and rounded at the other, with a fairly hard testa. Number of seeds per kg is 4800-5200 and about 3880 fruits weigh 1 kg.

Distribution

H. binata is a native species of tropical Southeast Asia. Its distribution covers Afghanistan, Bangladesh, Brunei, Cambodia, India, Indonesia, Iran, Laos, Malayasia, Myanmar, Nepal, Pakistan,New Guinea, Philippines, Thailand and Vietnam. In India the tree is found in the dry savannah forests of the Deccan peninsula, Central India and parts of U.P. and Bihar.

Silvicultural Requirements

The maximum temperature in the habitat of *H. binata* varies from 43 to 47 °C and minimum 1 to 10 °C, the average being 22-34 °C. It is sensitive to frost when young but grows more frost hardy with age. Young shoots are sensitive to fire but recovery is good. It thrives best in areas receiving an annual rainfall of 500 to 1000 mm. The tree occurs up to an altitude of 760 msl. It can grow on a wide variety of geographical formations and soils such as dry shallow soil and rocky ground, porous sandy-loams and reddish gravelly sandstones, conglomerates, granites and schist. It tolerates acidic to neutral soil. It extends its root even in hardpan of $CaCO_3$. Characteristically, it is found in teak forests, dry savannah and degraded dry deciduous forests.

Silvicultural Characters

H. binata is a moderate light demander and partial shade bearer. It is frost hardy and highly drought resistant. It loves dry climate and establishes well in rocky terrain. It pollards well and coppices indifferently. It gives out good root suckers.

Phenology

The flowers appear during July to September. The light-winged pods ripen during April or May. The seed is collected between June and July. The seed dispersal is through wind. There is some sporadic seeding every year, but gregarious seeding takes place on average every 3-5 years, according to locality. Seed may sometimes retain viability for 1 or even 2 years. Trees raised from seedlings begin to

seed in 20-25 years. Coppice shoots may bear seed as young as 7 years.

Propagation Technology

Through Seeds

Germination can be hastened by soaking seeds in water. Raised beds of 10 m x 1.5 m are prepared with standard potting mixture of sandy loam soil with 10 kg FYM and drenched with Aldrin. The seeds are sown at a spacing of 10 cm x 10 cm. Germination may start in 10-15 days and complete in about 5 weeks. Germination is epigeous. Seeds should be covered lightly. Shading of nursery beds is necessary as exposure of tiny seedlings to hot sun results in large scale mortality in dry localities. Mulching and shade improve growth and survival of seedlings. Seedlings of 15-20 cm height are transplanted in polybags and kept in the open with partial shade. Watering should be given two times per day for better survival.

Vegetative Propagation

Stump Planting

The stumps can be made from one-year-old seedlings and should contain 4 cm of shoot and 13-15 cm of roots. The stump can be treated with cow's urine for six hours and should be planted in big polythene bags or nursery beds.

Air Layering

Select the branches with 1-1.5 cm diameter and 40-50 cm length on matured tree. Girdle the bark of 2-2.5 cm width cylindrically with a sharp knife around the axis of healthy side dropping branchlets of 10-15 cm away from the base of main branch. Prepare an application of 1000 ppm IBA+500 ppm Kinetin+50 ppm vitamin B complex in distilled water and in 3% agar medium. Apply the prepared solution on debarked area for rooting. Cover the scalped part with moist sphagnum moss and wrap with plastic transparent ribbon of 2"

width. After 30 days branches are detached from mother plants. The tip of airlayed branches are cut off and planted in polythene bags with 1:1 soil and sand mixture.

Cultural Operations

Planting

Site preparation includes ploughing the land 2-3 times and making 30 cm x 30 cm x 30 cm pits before the onset of monsoon. The pits are filled with farmyard manure and topsoil. Planting is done immediately after the first rains. At the time of planting, 5 kg of well rotted FYM, 50 gm gypsum, 50 gm SSP and 50 gm Murate of Potash with 5 gm Phorate are applied. The seedlings can be transplanted into fields after 12 months. Also, the sprouted stumps can be transplanted into fields after 12 months during the rainy season. The vigorous growth of the seedlings starts only after they are 4-6 years old. Square, rectangular and boundary planting is preferred. The standard spacing for agroforestry plantation is 5 m x 5 m or 4 m x 5 m for timber, and 10 m x 10 m for fodder. In boundary plantation, trees are planted 4 m apart in single or double rows.

Tending Operation

For timber or pole production, *H. binata* trees are trained to grow straight without much forking. It is helpful to weed around the seedlings to eliminate competition from other plants. This is especially important during the first months when the roots of the trees are not well established yet and weeds will compete for water and nutrients. Alternatively, a cover crop may be planted to choke weeds and reduce labour costs. A cover crop also reduces soil erosion and conserves soil moisture. Generally, intercropping in trees controls the weed growth. Also, two manual weedings during establishment help protect the healthy growth of trees.

Pruning should be conducted periodically to remove lower branches that have grown too large or no longer produce flowers. Lower branches need to be pruned to get straight and knot-free

boles for good market price. Generally, in the Bundelkhand region of Rajasthan, pruning is carried out just before the rabi season.

An average of 20 kg leaves per tree of *H. binata* can be obtained by lopping the lower part of the crown every year. Lopping in May takes less time for recoupment than in December. However, studies show that lopping in winter results in recovery during the next season. Lopping should be restricted to the lower two-thirds of the crown and lopped trees should be rested for two seasons (Deb Roy et al. 1980).

The tree pollards well even up to a comparatively advanced age, and old pollards when re-pollarded almost invariably produce abundant new shoots. Coppicing ability of the tree is rather poor. Generally, high density plantations like 400, 800 or more trees per hectare are thinned out to develop the required size of merchantable timber. Mechanical thinning is used in large plantations.

In agroforestry, vertical spread of the tree is a desirable feature; therefore, trees raised in agroforestry systems must be vertically trained to avoid shade and light competition in understorey crops.

Tree protection

Diseases

Fusarium oxysporum causes wilt in *H. bina*ta. Symptoms of wilt disease start from the tip of the seedling and along the margin of the leaves. Subsequently, the disease advances downward causing defoliation and eventual death of seedlings. Application of Bavistin and Dithane M-45 controls the fungus.

Pests

Longicorn beetle *Aeolesthes holosericea* attacks stumps and felled timber. Prophylactic measures against borer attack in freshly felled timber in storage for longer period may be adopted. Spraying with gamma BHC (Lindane 1%), Malathion or Fenitrothion 2% water emulsion spray is effective to provide protection for longer period in storage.

Suitable Agroforestry Systems

The common agroforestry systems are as follows:
Agrisilviculture: Anjan+wheat, anjan+black gram, anjan+mustard
Silvipasture: Anjan+*Cenchrus ciliaris*

***Hardwickia binata* in an agroforestry system**

Harvesting and Yield

In studies at Bijapur, 8-year-old trees spaced at 5 m x 2 m had a standing biomass of 9.9 kg/tree (dry weight) in which the stem constituted 75%. Leaf yield from loppings was 0.9 kg/tree/yr. In intercropping studies, rabi sorghum yielded 52% higher than in no-tree control when the trees were 6-7 years old (Korwar, 1994).

***Hardwickia binata* plantation**

Utilization

H. binata yields an extremely hard, heavy and durable timber. The wood is largely used for beams and mine props, bridge and house construction, agricultural implements, carts and wooden wheels and railway sleepers. Leaves are used as cattle fodder, containing about 9-11% crude protein. The species is regarded promising for fodder production in arid zone areas and can be maintained as protein bank. Leaves are also used as manure. It is an excellent firewood and good charcoal tree. The bark yields a red-brown fibre used for ropes and other purposes. Branches are lopped for manure; leaves can be used as mulch.

References

Deb Roy, R., Shankaranarayana, A. and Pathak, P. S. 1980. Fodder trees and their importance in India. *Indian Forester* 106: 306-311.

Korwar, G.R. 1994. *Hardwickia binata* -- a Promising MPTS for Agroforestry in Dryland Areas. *In*: Multipurpose Tree Species for Agroforestry in India. Hegde, N.G. and J. N. Daniel (eds). BAIF Development Research Foundation 'Kamdhenu', Senapati Bapat Road, Pune, India

Chapter 17

Jatropha curcas L.

Family: Euphorbiaceae
Common name: Jatropha, Ratanjyot
Trade name: Physic nut
Origin: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama

Botanical Characters

The genus Jatropha is a diploid with chromosome number (2n) 22, and contains about 175 species in the world. In India, 12 species are found scattered in various states. Jatropha is a multipurpose non-edible oil yielding perennial shrub which originated in Tropical America and West Asia. The species is monoecious, with male and female flowers on the same plant. Fruits form at the end of branches in bunches of 5-20 and are about 40 mm long. Each fruit contains 3 seeds, though occasionally 4 or 5 seeds. Jatropha seeds look like black beans and are on average 18 mm long, 12 mm wide and 10 mm thick. These dimensions vary between seeds from the same plant or provenance and between seeds from different provenances. Single-seed weight is 0.5 to 0.8 gm, with an average of 1333 seeds per kilogram.

***Jatropha curcas* plant in field**

Distribution

From the Caribbean, *Jatropha curcas* was probably distributed by Portuguese seafarers via the Cape Verde Islands and former Portuguese Guinea (now Guinea Bissau) to other countries in Africa and Asia. In India, it is found in Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Gujarat, Punjab, Haryana, Chhattisgarh, Orissa and some of the North-Eastern states. It is a hardy plant and is found wildly growing in arid and semi-arid regions of the country on degraded soils having low fertility and moisture.

Silvicultural Requirements

Jatropha grows in tropical and sub-tropical regions, with cultivation limits at 30º N and 35º S. It also grows in lower altitudes up to 500 metres above sea level. It can be cultivated successfully in the regions having an annual rainfall of 500-1200 mm and optimum temperatures between 20 ºC and 28 ºC. The plant is well adapted to conditions of high light intensity and is unsuited to growing in shade and areas getting heavy frost. It is known for its ability to survive in very poor dry soils, but its best growth occurs in sandy and loamy soils having at least 45 cm depth. Heavy clay soils and waterlogged conditions should be avoided. It can grow in alkaline soils, but the optimum soil pH should be within 6.0 to 8.5.

Phenology

Jatropha sheds its leaves during January-March and new flushes of leaves appear during March-April. The flowering and fruiting occurs twice a year: in March-April, and then in September-October (flowering); and May-July and November (fruiting).

Propagation Technology

Through Seeds

Jatropha is normally propagated through seeds. Seeds should be taken from mature yellow or brown fruits. The seeds are graded

and only the largest ones selected for sowing. Pre-treatment to soften or break the seed coat will enhance germination. In tests, pre-soaking in cow dung slurry for 12 hr gave 96% germination compared to soaking in cold water or nicking the seed coat which gave around 72%. Germinated seeds are sown in polybags 10 cm x 20 cm filled with red soil, sand and organic matter in the ratio of 1:1:1, respectively. Seedlings may be planted out after 2 to 3 months, when they attain a height of 30–40 cm and before taproot development becomes overly restricted.

One to two seeds of Jatropha can be sown directly in the ploughed and marked field. The seeds should be planted 4–6 cm deep, with two per station, and later thinned to one. Since 1300 seeds weigh approximately 1 kg, the seed rate for planting one ha (at 2500 plants per ha) is about 4 kg. The main field should be ploughed and spots may be marked and enriched with FYM. Twenty gram Urea, 120 gm Single Superphosphate and 60 gm Muriate of Potash should be applied after establishment of the plant. Seedlings grown by this method will take more time for establishment and have slower growth in the initial period. Frequent weeding is required. Similarly, soil working around the seedlings will boost the growth and improve the moisture and rainfall infiltration.

Nursery seedlings of Jatropha

Vegetative Propagation

Cuttings of 25 to 120 cm length are taken from the middle or lower parts of one-year-old branches. These can be inserted 10–20 cm into the soil in shaded nursery beds for bare root transplanting or planted into polyethylene bags or planted directly into their final planting sites. Cuttings may be prepared in the month of March, when plants shed most of their leaves. These cuttings are planted in nursery beds at a spacing of 30 cm x 30 cm or in polybags. Pre-treatment of

stem cuttings with 300 ppm IBA (Indole butyric acid) solution for 5 minutes is desirable. Sprouting starts within 7 days of planting. Plants propagated by cuttings will normally produce seeds within a year of planting and growth is rapid. Rooting takes two to three months, so cuttings should be planted ahead of the rainy season for the rooting to coincide with the start of the rains. Mini-cuttings may be prepared by laying cuttings horizontally in rooting media and, when the nodes have sprouted and produced adventitious roots, cut the stems at the internodes and plant them into polyethylene bags for further growth in the nursery before planting them out.

Vegetative propagation through cuttings of Jatropha

Raising plantlets from tissue culture is being researched and protocols have been developed but, as it is a latex-producing plant, the procedure is not straightforward. There are no reports on tissue culture of Jatropha being applied on a large scale.

Cultural Operations

Planting

Generally, the planting sites should be made ready before the onset of monsoon. Pits of 30 cm x 30 cm x 30 cm may be dug and filled with a mixture of 1.0 to 2 kg of FYM, 50 gm of DAP and methyl parathion (2% dust), and 5 to 10 gm of thimmet granules. It will protect the young saplings from termite damage. Seedlings drenched with cow dung and urine solution (5:1) at 200 ml/plant perform better.

Spacing decisions should be based on the environment, i.e. how it affects competition among trees for water, light and nutrients. Semi-arid, low-input systems should use wider spacing such as 3 m x 2 m or, 3 m x 2.5 m or 3 m x 3 m. For hedgerow/ boundary

plantation of fields, the spacing should be 1 m x 1 m. Alternate planting in succeeding rows will minimize mutual shading. At least 2.5 m between trees allows easier passage for fruit pickers, while a 5-m alley at every fourth row facilitates access by carts. The number of trees per hectare at planting may range from 1100 to 3300.

Tending Operations

Seedlings are susceptible to competition from weeds in the first year. For better performance and establishment, fields are kept free from weeds. At least two manual weedings should be given during the first year.

Irrigation is a must immediately after planting. Irrigation should be given on the third day after planting. The irrigation at fortnightly interval is necessary to ensure year-round production of flowers and harvest of seeds. Jatropha shows a flowering response to rainfall. After short (one month) periods of drought, rain will induce flowering. Thus, the cycle of flowering can be manipulated with irrigation.

Pruning of Jatropha

In Jatropha, the terminal bud should be nipped to induce secondary branches. Likewise the secondary and tertiary branches should be pinched or pruned at the end of first year to induce a minimum of 25 branches at the end of second year. Once in 10 years Jatropha may be cut back leaving a one-foot height from the ground level for rejuvenation. The growth is quick and the plant starts yielding in about a year. This is useful to induce new growth and to stabilize yield. In semi-

arid regions, digging contour trenches and basins around individual plants aids water entrapment and infiltration. Pruning during the dry or dormant season is important to increase branching and the number of tip-borne inflorescences, as well as to form a wide low-growing tree that is easier to harvest. The stem and branches may be pinched out at six months to encourage the development of lateral shoots and branches. The branch tips are pruned again at the end of the first year. In the second and subsequent years, branches are pruned by removing around two-thirds of their length. For early flowering, GA at 100 ppm may be sprayed.

Tree Protection

Pests

Insects such as leaf eating beetles, thrips, leafhoppers, grasshoppers, caterpillars and leaf miner damage Jatropha plantations by feeding on their foliage. Bark eater and capsule borer are the two major pests affecting the plant. They may be controlled by spraying Endosulphan at 3 ml/litre of water. Collar rot may become a problem in the beginning and may be controlled by spot drenching of 1% bordeaux to the affected and neighbouring plants. The inflorescence and capsule-borer, *Pempelia morosalis*, also causes economic damage by webbing and feeding on inflorescences.

Longicorn beetle, *Acanthophorus rugiceps* Gahan, also causes extensive damage to Jatropha roots. It may be controlled by adopting any of the following methods: soil drenching with chlorpyriphos 20% EC, dusting soil around the main stem with methyl parathion 2D, applying phorate 10G granules in the root zone and spot application of dichlorvos 76% EC by drilling a long, narrow and deep hole in the soil near the root zone of infested plants (Prabhakar et. al. 2012).

Suitable Agroforestry Systems

Trials conducted in Uttar Pradesh revealed that groundnuts could be grown successfully between lines of Jatropha with a spacing of 3 m apart and pruned down to 65 cm. The groundnuts were planted in

the dry season with limited irrigation, when there was no leaf cover from Jatropha. It was found that this system helped in weed control and the growth of Jatropha was better than the control (Singh et al. 2007).

Yield

Due to uneven ripening of the fruits, harvesting of Jatropha is mainly done by hand. This has a high impact on the production costs of Jatropha oil. Fruits are ready for harvesting around 90 days after flowering when their colour changes from green to yellow-brown. The fruits are dried and seeds removed by hand, by crushing with a wooden board or by using a mechanical decorticator. Seeds are sun-dried for four days until the moisture is brought to 6-10% before oil extraction.

Bio-fencing of Jatropha

Wherever Jatropha is cultivated under irrigated conditions, the flowering is throughout the year, but economic yield starts only after 3 years age. Its yield is estimated as 3000 kg seeds/acre at 3 kg of seeds per plant). The oil content of Jatropha seed can range from 18.4–42.3%. The yield also depends on the planting material selected for plantation, management of plantation and factors related to locality.

Utilization

Jatropha oil is an environmentally safe and a promising substitute for diesel, kerosene and other fuels. Jatropha soap is made by adding a solution of sodium hydroxide (caustic soda) to Jatropha oil**.** About 50% of the original seed weight remains as seed cake

residue, mainly in the form of protein and carbohydrates. It may be used as fertilizer, fuel or, if it is detoxified or if non-toxic varieties are used, it can be used as animal feed. Jatropha seed cake makes an excellent organic fertilizer with a high nitrogen content. Fruit hulls and seed shells can be used as fuel. Jatropha can be grown as hedge (bio-fence) to protect the fields.

References

Prabhakar, M., Prasad, Y.G., Rao, G.R. and Venkateswarlu, B. 2012. A new record of longicorn beetle, *Acanthophorus rugiceps,* as a root borer on physic nut, *Jatropha curcas* from India with a description of life stages, biology and seasonal dynamics. *Journal of Insect Science* 12:141.

Singh, R.A., Kumar, M. and Haider, E. 2007. Synergistic cropping of summer groundnut with *Jatropha curcas* – A new two-tier cropping system for Uttar Pradesh. *Journal of SAT Agricultural Research* 5 (1): 1-2.

Chapter 18

Leucaena leucocephala
(Lam.) de Wit

Family: Leguminosae
Common name: Subabul, Leucaena, ipil-ipil
Trade name: Subabul, ipil-ipil
Origin: Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Spain, USA

Botanical Characters

Leucaena leucocephala is a small, variably shrubby and highly branched to medium sized tree with a short, clear bole to 5 m, upright angular branching and a narrow open crown, and which can grow upto 15 m tall. Bark on young branches is smooth, grey-brown and deep red on older branches and bole. This evergreen plant is deep rooted. It often has a combination of flowers, immature and mature pods all present on the tree at the same time. Leaves with 6-9 pairs pinnae; pinnular rachis 5-10.2 cm long, leaflets 9-16 mm long, 2-4.5 mm wide, 13-21 pairs per pinna, slightly asymmetric, linear-oblong to weakly elliptical, acute at tip, rounded to obtuse at base, glabrous except on margins. Flower heads 12-21 mm in diameter, 100-180 flowers per head, in groups of 2-6 in leaf axils, arising on actively growing young shoots, flowers white. or pale cream-white. Pods 11-19 cm long, 15-21 mm wide, 5-20 per flower

***Leucaena leucocephala* tree**

head, linear-oblong, acute or rounded at apex, flat, 8-18 seeded, mid- to orange-brown, glabrous and slightly lustrous or densely covered in white velvety hairs, papery, opening along both margins. Seeds hard, dark brown with a hard, shining testa, 6.7-9.6 mm long, 4-6.3 mm wide, aligned transversely in pod (Orwa et al. 2009).


Flowers (left) and pods of *Leucaena leucocephala*

There are three basic types of Leucaena trees: Hawaiian, Salvador, and Peru. There are also crosses between these.

1. The Hawaiian type is short and bushy. Because its yield of wood and foliage is low compared to the other two types, this would probably be a poor choice.
2. The Salvador type (Hawaiian giant) is tall and tree-like. The trees can grow 60 ft in height in five years. The best varieties of this type are K8 (Mexico), K28, K67 and K72. K67 is the best variety for producing large quantities of seed.
3. The Peru type is tall with extensive branching. The trees are good for forage. Good varieties are K6 and K62. An excellent forage-type Leucaena is the Cunningham (K500) which was developed in Australia. It is a cross between the Salvador and Peru types.

Distribution

In India Leucaena was tried in the recent past in Andhra Pradesh, Karnataka, Tamil Nadu, Himachal Pradesh and also in Uttar Pradesh and almost became naturalised in some parts. However, it received increased attention only in the 1980s, when it was planned to introduce the fast growing and higher yielding varieties to meet the fuelwood crisis. As a re-introduction it has been extensively

planted in Maharashtra, Gujarat, Punjab, Haryana, UP, Tamil Nadu, Karnataka, Bihar and West Bengal.

Silvicultural Requirements and Characters

Leucaena is a tropical species requiring warm temperatures (25-30 °C) for optimum growth. At higher latitudes and at elevated tropical latitudes growth is reduced. Brewbaker et al. (1985) suggested that temperature limitations occur above 1000 m elevation within 10 °C latitude of the equator, and above 500 m elevation within the 10-25 °C latitude zone. Leucaena is not tolerant of even light frosts which can cause leaf sheding. Heavy frosts kill all above-ground growth, although the crowns survive and regrow vigorously in the following summer with multiple branches. It grows well only in sub-humid or humid climates with moderate dry seasons of up to 6-7 months. It tolerates fires and can regrow after being burned to the crown by slower fires. It is an aggressive colonizer of ruderal sites and secondary or disturbed vegetation in many places. This has been attributed to its precocious year-round flowering and fruiting, abundant seed production, self-fertility, hard seed coat, and ability to re-sprout after fire or cutting.

Leucaena is a light demander. It grows well in a wide range of rainfall environments from 650 to 3000 mm. However, yields are low in dry environments and are believed to increase linearly from 800 to 1500 mm rainfall. Leucaena is quite drought tolerant even during establishment. Young seedlings can survive extended periods of dry weather. Soil and plant studies have confirmed that Leucaena exhibits better drought characteristics than a number of other tree legumes (Swasdiphanich, 1992).

The species grows well in loamy soils, clayey loam and sandy loam. Leucaena is not tolerant of poorly drained soils, especially during seedling growth, and production can be substantially reduced during periods of waterlogging but, once established, it can survive short periods of excess moisture. It does best on deep, well-drained, neutral to calcareous soils. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay soils and requires good levels of phosphorus and calcium for

best growth. It has a long strong tap root and can penetrate deep in compacted soils. The species has foliage which fertilizes the soil, as the fallen leaves decompose fast and form good humus to add soil nutrients. The species is an excellent nitrogen fixer thereby helps to augment the soil fertility. Cattle and goats like the taste of Leucaena fodder, so they can cause extensive damage to the tree if grazing is not controlled.

Phenology

Leucaena is an evergreen species; however, under frosts or prolonged droughts it sheds its leaves but regains when the normal conditions return. The Hawaiian type Leucaena flowers almost the year-round except during winter under north India conditions. The Salvador and Peru types flower sporadically and seasonally, usually twice a year, and are poor seeders. Leucaena starts flowering at an early age and producing good seed from the second year onwards. Fruit formation takes place early and a cluster of flat, almost straight pods is soon formed from each flower head.

Propagation Technology

Through Seeds

Seeds come out of pods which grow in clusters, from mostly self-pollinated flowers, which look like fluffy white ball. The seed has a waxy white coat, and needs to be treated. Giant types have about 20,000 seeds in a kilogram. In general there are 30,000 seeds in a kg of 100% purity with about 6% moisture. Ripe pods should be collected before they split and dried in the sun for 3 to 4 days. The pods then split, and seeds can be gathered by sieving. Seeds are viable for three to four years.

Freshly harvested seeds of Leucaena are hard due to an impermeable waxy coat, so they need pre-treatment before sowing: soaking in hot water for 10 minutes, or in cold water for 3 to 4 days. Concentrated sulphuric acid can also be applied for 15 minutes to soften the seed. About 70 to 80% seeds germinate within a week.

Pre-treated seeds should be sown in polybags (12.5 cm x 20 cm), filled with a soil mixture to which Rhizobium inoculum (soil from older plantations) is added at 250 gm for 20 kg of seed. Pre-treated seed can also be sown in nursery beds of 40 ft x 4 ft thinly covered with soil (soil cover should be 3/4th the thickness of seed). Seedlings, when 10 cm tall, can be pricked out and planted in polybags filled with soil mixture.

Vegetative Propagation

Leucaena has been reported to have been successfully propagated by all the major vegetatively propagating techniques including leafy cuttings, leafless stakes, air-layering, grafting and in vitro culture. Single-node leafy and leafless cuttings harvested from one-year-old, 1.3 to 1.5 m tall seedlings were successfully rooted in a non-mist propagator**.**

Cultural Operations

Planting

In general, the site should be cleared of vegetation and burned, ploughed, or herbicide-killed before planting. In cultivated lands, the best stand establishment is obtained using land preparation similar to that used for row crops or forage plantings. This is especially true for direct seeding where weed competition during the establishment period can lead to failure. Tillage can be done more roughly for plantations by seedlings, although a thorough tillage on cultivated lands generally results in fewer weed problems after planting.

Direct sowing of seed during monsoon gives good results, but the plants grow slower than nursery-raised seedlings and if there is prolonged drought the germinated seeds may dry up. Leucaena can be planted by seed or 'bare stem' seedlings. Large areas are best planted by seed in rows into fully prepared seed beds or into cultivated strips in existing grasslands. Seeding rates of 1-2 kg/ha at depths of 2-3 cm are usually recommended in rows 3-10 m apart. Sowings are best made early in the growing season, but when rainfall

is reliable good weed control measures (cultivation and herbicides) should be used to minimise competition. Leucaena seedlings are very susceptible to competition in the root zone.

As Leucaena is a good coppice tree, recent trials with stump planting have given good success. Good pre-treated seed is sown on nursery beds. The seedlings which are 3 to 4 months old, and when the collar thickness is that of an index finger, are taken out of the beds and stumps formed by cutting the shoots and roots. The length should be 22.3 to 30 cm The stump should have only about 20 cm of the shoot.

Spacing can be varied to suit the end use. For producing fodder, the spacing can be 50 cm x 50 cm. For fuelwood the spacing can be 1 m x 1 m. For pulpwood, as the minimum girth is 10 cm, and if harvesting is done in the fourth year, the best spacing will be 3 m x 1.5 m. Farmers usually plant at 1.25 m x 1.25 m spacing. Leucaena may be planted as single plants, single hedgerows or multiple hedgerows depending on its use. In widely spaced rows for grazing, grasses may be planted between Leucaena rows to increase total fodder production.

Fertiliser application at planting is necessary on most soils to achieve vigorous seedling growth as many tropical soils are infertile following years of intensive cropping, leaching and erosion from high intensity rains. Leucaena is particularly susceptible to phosphorus deficiency and is dependent on vesicular arbuscular mycorrhizae (VAM) to extend the capacity of its root system to access immobile nutrients such as phosphorus. In soils low in phosphorus, or low in natural VAM activity, quite high rates of phosphorus (100 kg P/ha) should be applied. Leucaena is also sensitive to calcium deficiency as this reduces nodulation. Other nutrients may be necessary if soil tests indicate a deficiency, to ensure vigorous early growth of seedlings. In very acid soils (pH < 5.0), liming is necessary.

In soils with a pH between 6 and 8, nutrients are usually adequate, but not always. Basic soils with pH above 7.5 may be deficient in nutrients such as iron and zinc, and these can be used to supplement phosphate. In acid soils with pH of less than 6.0, low fertility is common and calcium deficiency may be a major limiting factor. Dolomite at 200 kg/ha can be added to supply sufficient Ca

and Mg. Rock phosphate could replace Superphosphate at 200 kg/ha plus 100 kg/ha of calcium sulfate.

Tending Operations

Weeds are a major cause of slow establishment or even failure of seedlings. Regular weeding, till plants are 1 to 2 m tall, gives best results. Weeding and soil working around the plants to a radius of 0.5 m should be done at least thrice in the first year, and as many times as necessary in subsequent years.

Singling of multiple shoots, by retaining one or two at each plant, will give good girth increment of the retained shoot. If pruning is to be done to obtain green manure or cattle fodder, it should be limited to two-thirds of the bole, leaving intact the one-third of the crown. Pruning of dead or dying branches is usually unnecessary in Leucaena plantations. The species is highly self-pruning at normal densities. Dead branches fall early, or are easily knocked from the tree and gathered as fuelwood.

Thinning involves the removal of off type and immature trees to reduce plant populations, thereby accelerating incremental diameter growth and improving the form of remaining trees. This practice is less important in Leucaena than with other tree species since Leucaena is a self-pollinating plant with little or no true differences from plant to plant. Observed differences, if any, are primarily due to micro environment, and to competition at high population densities. Thinning is normally uneconomical in capital-intensive projects, especially when population densities are high. Thinning can be practiced in pulpwood or saw timber plantations to improve stem form, e.g. establishment at 1 m x 1 m with thinning to 1 m x 2 m or 2 m x 2 during the second or third year.

Tree protection

Major Pests

The psyllids (*Heteropsylla cubana*) or jumping lice are small aphid-like insects adapted to feeding on young growing shoots of Leucaena. Mild infestations cause distortion of leaves while heavy infestations

result in loss of leaves and attack by secondary moulds which feed on the sticky exudate of psyllids. *Menochilus sexmaculatus*, a coccinellid predator is found to be effective on Leucaena psyllid. Mound building ants cause damage by eating the leaf and bark of young seedlings. Inch worms and twig borers also damage young seedlings, particularly during drought when the seedlings are weak. Mature trees are generally safe. When pests are beyond threshold level, say, 10 to 15% of the plants are affected; spraying appropriate insecticides should be considered in safe limits in order not to affect the predators.

Major Diseases

Fusarium semitectum, which causes gummosis, is the most important fungus. Though healthy and giant types are resistant to this fungus, some other varieties are seriously affected. Another fungus, which causes canker, is *Phytophthera dreschleri*. Borer insects introduce a fungus on seeds and young pods. This can be controlled by eliminating the insect by use of systemic insecticides. Damping off can occur in wet soils, generally in densely packed seedlings in a nursery. This can be controlled by applying copper sulphate with irrigation. *Comptomeris leucaena* causes leaf spots and ends in defoliation. Weak plants are the main targets. For fungal diseases the best fungicide is Bavistin, which should be sprayed in the nursery and young plantations. Seedlings may also be damaged by snails, livestock, rats, rabbits, deers, monkeys, etc. A good fence will be necessary where these threats are in abundance

Suitable Agroforestry Systems

Leucaena is a suitable species for hedge row intercropping. It is one of the best species used for the production of green manure in alley-cropping systems. Its leaves, even with moderate yields, contain more than enough nitrogen to sustain a maize crop. The leaves decompose quickly, providing a rapid, short-term influx of nutrients. It has even been suggested that the leaves decompose too rapidly, resulting in leaching of nutrients away from the crop-rooting zone before they are taken up by the crop. This also means

Leucaena-based agroforestry system

that they have little value as mulch for weed control. The tree has the potential to renew soil fertility and could be particularly important in slash-and-burn cultivation, as it greatly reduces the fallow period between crops. Leucaena is one of the best fodder species and a key component in silvipasture systems.

Yield

Leucaena plantations can be harvested in the 4th year. The average yield is 70-75 t/ha. Farmers adopt a rotation of 3-4 years. Normally, they go for three coppice crops. As Leucaena is a good coppice tree, several harvests at 3-year intervals can be obtained, over a period of 40 years. Dry-matter productivity of Leucaena varies with soil fertility and rainfall. Edible forage yields range from 3 to 30 tonnes of dry matter/ha/year. Deep fertile soils receiving greater than 1500 mm of well distributed rainfall produce the largest quantities of quality fodder.

The most suitable cutting or grazing intervals to promote high yields vary with environmental factors. In general, longer intervals between defoliation increase total yield; however, the proportion of inedible wood may also increase leading to a decline in forage quality. At very productive sites, harvest intervals may be 6-8 weeks and up to 12 weeks at less productive locations. Harvest height has less influence on total yield than harvest frequency. The leaflets make a good fodder with 25 to 30% protein.

Utilization

Leucaena has multiple uses and is, therefore, referred to as a "miracle tree" worldwide. The leaves are highly nutritious for ruminants. The species is capable of producing a large volume of medium-light hardwood for fuel (specific gravity 0.5-0.75) with low moisture and a high heating value, and makes excellent charcoal, producing little ash and smoke. It also can be used for parquet flooring and small furniture as well as for paper pulp. Leucaena poles are useful for posts, props and frames for various climbing crops (Brewbaker et al. 1985). Leucaena hedges are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth. The calorific value of air-dried (15% m.c. wet basis) Leucaena wood is about 3,900 kcal/kg (4,640 kcal/kg oven dried), similar to that of other non-resinous hardwoods. The burning properties are good (steady flame, low smoke and sparks). The major value of Leucaena is still associated with its high productivity as a fuelwood, and this applies to both village and industrial use.

Leucaena is used for the production of paper pulp and dissolving pulp. The pulp is blended with long-fibre pulp to produce printing paper. The fibre is also useable for rayon and other products. Fibre characteristics are within the range expected for fast-growing tropical hardwoods. Because pulping operations must be on a large scale and are highly sensitive to the cost of wood, development of Leucaena plantations for this purpose must be closely integrated with requirements of the pulping plant.

The bark is thin (8% of dry weight at age 7) and easily removed. Silica and extractive contents are low (2% dry weight), thus minimizing consumption of alkali in chemical pulping. The holocellulose content (71%) is somewhat higher than the average for hardwoods (64%).

References

Brewbaker, J.L., Hegde, N., Hutton, E.M., Jones, R.J., Lowry, J.B., Moog, F. and van den Beldt, R. 1985. Leucaena - Forage Production and Use. NFTA, Hawaii. 39 pp.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. 2009. Agroforestry tree Database:a tree reference and selection guide version 4.0. International Centre for Research in Agroforestry, Nairobi, Kenya

Swasdiphanich, S. 1992. Environmental influences on forage yields of shrub legumes. PhD thesis, The University of Queensland.

Chapter 19

Melia dubia Cav

Family: Meliaceae
Common name: Persian Lilac, White Cedar, Malabar Neem, Maha Neem
Trade name: Malabar Neem, Wood/Melia
Origin: India

Botanical Characters

Melia dubia is a fast growing, indigenous and economically important multipurpose tree species that grows naturally in certain parts of the Western Ghats of South India. The tree is deciduous to semi-evergreen, up to 25 m tall, with wide spreading branches of handsome foliage. Bark is dark brown, fibrous which peels off in long strips of rectangular shape. Found growing in the deciduous

***Melia dubia* trees in row planting**

forests and in the countrysides on wastelands. Leaves are compound, rich in essential oils, bipinnate to tripinnate, alternate, pulvinate; rachis terete to 30 cm long; petiole 0.3-1.2 cm; pinnae 3-8 pairs; leaflets 2-11 on each pinnate, opposite, 4.5-9 x 2-4 cm, ovate-elliptic, apex acuminate, base cuneate or attenuate, asymmetric, margin crenate, coriaceous, glabrous when mature; midrib raised above; secondary nerves of 10 pairs, gradually curved; tertiary nerves broadly reticulate. Inflorescence is an auxiliary panicle, 12-20 cm long; flowers are small, greenish white, honey scented, appearing in bunches with new flush of leaves (January - March). Fruit is a drupe, ovoid or ellipsoid with longitudinal ridges, pulpy and yellowish on ripening with a sweet smell. Each fruit consists of 3-4 seeds. Fruits have a hard endocarp. Therefore quite difficult to germinate. The seeds weigh 250-320 in number to a kilogram (Nuthan et al. 2009).

Distribution

Melia is indigenous to the Western Ghats of Southern India and is common in moist deciduous forests of Kerala. It occurs in Sikkim Himalayas, North Bengal and upper Assam, Khasi hills of Orissa, Northern Circars, Deccan Plateau and Western Ghats at altitudes of 1500–1800 m. It grows rapidly and is used for afforestation. Outside India, it is found in Sri Lanka, Malaysia, Java, China and Australia.

Silvicultural Requirements

In the natural habitat of Melia, the absolute maximum shade temperature varies from 27.5 to 37.5 °C and minimum 0 to 15 °C. It does well in moist regions with a mean annual rainfall exceeding 1000 mm. It is commonly found in the hills at elevations ranging from 600 to 1800 m. The tree is a light demander, the seedling are suppressed under shade. Seedlings tolerate some frost but severe frost kills them. It is susceptible to damage by fire and saplings suffer from browsing. It grows on a variety of soils. However, deep fertile sandy loam soils show optimum growth, while shallow gravelly soils show stunted growth.

Phenology

The tree is leafless for a short time from December to February. New leaves appear in February-March along with the flowers. The fruits ripen during the cold season from October to February.

Propagation Technology

Through Seeds

Seeds are collected from ripened fruits (January–February) by rubbing, and are washed, dried and stored in sealed tins. The germinability of the seeds is less than 25%. In nursery, the seeds are sown in raised beds. The best seed pre-treatment is with cow dung solution for one day. Studies at IFGTB, Coimbatore, India reveal that germination could be as high as 60% without any pre-treatment. Seeds are sown during March-April in drilled lines, 5 cm apart, in farm-yard manure medium in the ratio of 2:1. About 6-7 kg of dried drupes containing about 1500 seeds are required for one standard nursery bed. The seeds sown should be watered twice a day. At places where daytime temperature is not very high, or where nursery beds are in shade, the bed should be covered with a tarpaulin sheet to retain temperature in the medium. Germination occurs within 90 days. The seedlings takes 6 months to complete their nursery stage.

Vegetative Propagation

Juvenile stem cuttings and coppice shoots respond well to 1000-2000 ppm IBA (liquid formulation). Coppice from older trees

Fig.1a. Dipping in antifungal medium

Fig. 1b. Planting of cuttings in polybags

responds better to rooting. Pencil-thick cuttings should be used for propagation (Fig. 1a, b). Thin shoots are susceptible to root rot. The shoots can be placed on sand medium and watered twice a day. A provision for drainage is a must as waterlogging destroys the shoots. Season also plays a major role in the rooting of cuttings. Drier seasons are conducive for rooting. About 75% rooting can be obtained. The species is very sensitive to transplantation and hence care must be taken while pricking seedlings from bed or transplanting rooted shoots to bags.

Mini clonal Technology

A mini clonal technology has been developed at FC&RI, Mettupalayam, India for Casuarina and *M. dubia.* Under this technology, superior clonal plants were planted in a mini clonal garden (Fig. 2) and provided with regular irrigation and fertilization

Fig. 2. Mini clonal garden of *Melia dubia* maintained at FC&RI, Mettupalayam, India

to promote shoot multiplication. In this method, the mother plants are planted at 10 cm x 10 cm spacing and 30-45 days old plants are ready for collection of cuttings. The newly induced shoots were separated from the plants and treated with 1500 ppm IBA (liquid formulation) and planted in 90 cc root trainers filled with decomposed coir pith. Rooting started in 15 days and 25 days old rooted plants were ready for hardening.

Under this method, rooting efficiency and uniformity increases significantly which leads to uniformity in establishment, growth and development. The mini clonal garden can be maintained for up to 5 years with an average production of 0.1 million plants per year.

Cultural Operations

Planting

Tillage can be done more roughly for plantations by seedlings, although a thorough tillage on cultivated lands generally results in fewer weed problems. The spacing followed varies with individual land holding, type of intercropping, availability of water and requirement of the farmer. Generally, while establishing plantations, 6-month old seedlings are planted in pits (45 cu cm). A spacing of 5 m x 5 m is optimal while a spacing of 8 m x 8 m is ideal. Farmers usually plant at a spacing of 3 m x 3 m or 3 m x 4 m. Annual pruning is done to get straight cylindrical boles.

Initial growth is hastened with daily watering and application of fertilizers once in three months for the first 3 years. The tree responds well to irrigation given every 10 – 15 days during non-rainy season. Application of N, P, K mixture of 25 -50 gm per tree, two times a year helps to augment growth. The fertilizer requirements can be scheduled on need basis depending on the growth and development of the tree.

Tending Operations

Normal tending operations such as ploughing, weeding and cleaning are carried out in *M. dubia* plantations, but in case of intercropping these operations are intensively focused on agricultural/horticulture crops. The operations like thinning, pruning and improvement fellings are also carried out in monocultures and bund-planted areas particularly when there is shade effect on agricultural crops and when demand for fodder and fuelwood exists. Pruning every 6 months controls branching.

Tree Protection

Pests

The IFGTB, Coimbatore has conducted a detailed assessment of important nursery pests of *M. dubia* (Jacob, 2011). The following insect pests have been reported:

Red spider mite: The mites occur in groups beneath the leaves and feed on epidermal tissues. Chlorosis can be easily located on the adaxial side in infested seedlings. Low- to medium-level infestation was found during June to July and November to December. Application of Derrimax 0.3 ml/litre of water can control the mite.

***Ferrisia virgata* - Mealybug:** Occasional incidence of mealybugs was noticed at low levels in seedlings. Application of Neem oil or tobacco extract on the underside of the leaves can control the mealy bug.

***Ascortis selenaria*:** This polyphagous defoliator attacks Melia seedlings during June to July and November to December. At a low infestation level, handpicking of caterpillars can be done to manage the pest. Adults are usually attracted to light, so light traps can be installed for a week after the first showers. At a high infestation level Methyl parathion (2 ml/l) can control the pest.

Leaf miners: Leaf miners also damage the leaves in nursery seedlings. A low level incidence was observed.

Fruit infesting beetles: Pulp of fallen fruits is eaten by beetles. However, seeds are not found to be attacked or damaged.

Other diseases: *Ganoderma lucidum* causes root rot in high-ainfall areas and *Corticium salmonicolor* causes stem and twig canker.

Suitable Agroforestry Systems

Melia is a good agroforestry species and is grown with a variety of crops Groundnut, chilli, turmeric, blackgram, papaya, banana, melon, foxtail millet and sugarcane are being successfully grown as inter-crops with Melia. The species performs exceedingly well when planted on bunds, attaining the harvestable size within four years.

***Media dubia*+foxtail millet agroforestry system**

Yield

The tree attains a volume of 15 cu ft at 15 years and earns a revenue of Rs 350 per cubic foot from the 5th year onwards (Warrier, 2014). Growth rate ranges from 20 to 25 cm per year when intensively managed and 6 to 8 cm per year in unmanaged plantations. It is expected to produce 12 to 15 cu ft (0.4 - 0.5 cu m) of timber in 5 years. Presently Melia fetches Rs 7300/- per tonne for billets of girth 50-120 cm and above Rs 370 per cu ft for trees which have attained a girth >120 cm.

Utilization

The sapwood is greyish white; heartwood light pink to light red turning pale russet brown on ageing. It is lustrous with dry feel,

very light (specific gravity 0.33; wt 21 kg/cu ft) straight grained and coarse and somewhat uneven-textured. The timber is not durable in exposed conditions but moderately so under cover. It is not so strong and durable as Neem. It seasons well if logs are converted in a green state. If left long, the log is liable to develop end-splitting and discolouration. The best method of dealing with the timber is to convert the logs immediately after felling and to open-stack the sawn material, preferably under cover, to avoid grey stain.

The wood is also used for packing cases, ceiling planks, building purposes, agricultural implements, pencils, match boxes, splints, kattamarans, musical instruments and tea boxes (Warrier, 2014). Thus, the species has a ready and assured market due to its multipurpose utilities. The species is also highly adaptable. The fruit of the plant is bitter. It is considered anthelmintic. It gives positive tests with alkaloid reagents.

References

Jacob, J. P. 2011. Insect pests of *Melia dubia.*Van Vigyan Newsletter. Vol 3 (2).

Nuthan, D., Chandrashekara, R., Sunil K. M., Vajranabhaiah, S. N. and Yogeesha, T.D.2009. Cultivation of *Melia dubia* on farm lands in Kanakapura taluk, Ramanagara district of Karnataka.Regional Centre, National Afforestation and Eco-Development Board.

Warrier, R.R.2014. Cultivation techniques for *Melia dubia. In*: Transfer of Tree Cultivation Technologies to Krishi Vigyan Kendras (KVKs) of Tamil Nadu and Puducherry. Institute of Forest Genetics and Tree Breeding, Coimbatore, India, pp 16-18.

Chapter 20

Pongamia pinnata (L.) Pierre

Family: Leguminosae (Papilionaceae)
Common name: Karanj, Karanja
Trade name: Karanj
Origin: Bangladesh, India, Myanmar, Nepal, Thailand.

Botanical Characters

Pongamia pinnata, popularly known as Karanj or Karanja is an important source of biodiesel. It is a drought tolerant, semi-deciduous tree, 15-25 m high, with straight or crooked trunk 50-80 cm or more in diameter and broad crown of spreading or drooping branches. Bark grey-brown, smooth or faintly vertically fissured. Leaves alternate, odd pinnately compound, 5 to 10 cm, hairless, pinkish-red when young, glossy dark green above and dull green beneath with prominent veins when mature. Leaflets 5-9, paired except at end, short-stalked, ovate elliptical or oblong, 5-25 cm x 2.5-15 cm, obtuse-acuminate at apex, rounded to cuneate at base, not toothed at the edges, slightly thickened.

***Pongamia pinnata* trees**

Inflorescence raceme-like, axillary, 6-27 cm long, bearing pairs of strongly fragrant flowers. Flowers 2-4 together, short-

***Pongamia pinnata* seeds**

stalked, pea-shaped, 15-18 mm long. Calyx campanulate, 4-5 mm long, truncate, finely pubescent; corolla white to pink, purple inside, brownish veined outside, 5-toothed, standard rounded obovate 1-2 cm long, with basal auricles, often with green central blotch and thin silky hairs on back; wings oblong, oblique, slightly adherent to obtuse keel. Pods borne in quantities, smooth, oblique oblong to ellipsoid, 3-8 x 2-3.5 x1-1.5 cm, flattened but slightly swollen, slightly curved, brown, thick-walled, thick leathery to sub-woody, hard, indehiscent, 1-2 seeded, short stalked. Seed compressed ovoid or elliptical, bean-like, 1.5-2.5 cm x 1.2-2 cm x 0.8 cm, with a brittle coat, long, flattened, dark brown, oily. Pongamia is an outbreeding diploid, with a chromosome number of 22.

Distribution

Pongamia is a medium-sized glabrous, perennial tree, native to the Asian sub-continent.The natural distribution of the species is along the coasts and river banks in India and Burma. In India, it is found in Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Dadra and Nagar Haveli, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Pondicherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal.

Silvicultural Requirements

Pongamia is native to humid and sub-tropical environments. It is a widely adaptable tree that grows under a wide range of climatic conditions. Areas with a temperature range of 5 to 50°C and well distributed annual rainfall of 600-2500 mm are suitable for its growth. It is a shade bearer and can grow under the shade, but not

a shade demander and grows well even with full overhead light. Mature trees can withstand waterlogging and some frost.

Pongamia can grow even in dry areas with poor, marginal, sandy and rocky soils. However, it does not like very dry sandy or very wet clay soils. It flourishes best in deep sandy loams with abundant moisture. Besides being drought tolerant, it is also tolerant to salinity and alkalinity. The soil pH range for good growth is 6-9.

Phenology

Pongamia sheds its leaves in March-April and develops new leaves from May onwards. Flowers appear in April to June and its pods ripen during March to May of the following year. Seed ripens from February to May. Seed production is prolific, with a single tree yielding 9–90 kg of seed per annum, indicating a yield potential of 900–9000 kg seeds/ha (assuming a plant density of 100 trees/ha)

Propagation Technology

Through Seeds

Pongamia is easily propagated through seeds either by direct sowing in the nursery bed or polybags during July-August or in situ sowing of seeds in the plantation fields. The ripened pods are collected during March to May and sun-dried. The seeds are extracted by light hammering or using a knife along the sutures. There are 1500-1700 seeds per kilogram. Soaking of seeds in IBA (30 ppm) or GA3 (20 ppm) for 24 hr enhances germination and seedlings develop large

Seed collection of *Pongamia pinnata*

root systems. The germinative capacity of fresh seeds varies from 60 to 89%. When stored in airtight containers, seeds may be viable for about a year.

One to two seeds of Pongamia can be sown directly in the ploughed and marked field. The main field should be ploughed and spots for sowing may be marked and enriched with FYM. After the seedlings get established, 20 gm Urea, 120 gm Single superphosphate and 60 gm Muriate of Potash (MOP) should be applied. Seedlings grown by this method take time for establishment and have a slow growth in the initial period. However, there should be enough moisture in the soil to support germination and seedling growth. Frequent weeding is required. Similarly, soil working around the seedlings will boost the growth and improve the moisture and rainfall infiltration.

In a nursery, Pongamia may be planted at a spacing of 7.5 cm x 15 cm. Seedlings may be grown in polybags filled with equal parts of soil, sand and FYM (1:1:1). Good quality seeds should be sown with one seed per bag at 2-3 cm depth. One gram of mycorrhizae (mixed culture) may be placed below the seed at the time of sowing to enhance the growth of seedlings.

Vegetative Propagation

Vegetative propagation of Pongamia could be done successfully through cleft grafting, which is cheap and economical. The success rate with cleft grafts can range from 92 to 98%. Macro propagation through grafting could be used for mass reproduction of this species.

Branch cuttings form the most widely used propagules for vegetative propagation through the application of synthetic and natural auxins to induce adventitious rooting. Indole-3-butyric acid (IBA) has been recommended as the best agent among different synthetic and natural auxins for root induction in cuttings of *P. pinnata* (Kesari et. al. 2009). Pongamia can be propagated through semi-hard wood (intermediate of soft wood and hard wood) and by hard wood (tertiary or secondary branches) cuttings (15 to 25 cm long and 0.5 to 1 cm in diameter) comprising 3-4 nodes. The root initiation and sprouting of cuttings can be induced by treating the

cuttings first with a fungicide and subsequently with auxins (IBA, IAA, and NAA) at different concentration ranging from 1.23 to 7.38 mM, respectively, for a maximum of 1 hr (Kesari et al. 2009). Multiplication of Pongamia by cuttings is difficult but grafting is easier. Cuttings of 2-3 cm thickness from the lower portion of the shoot and of 25-30 cm length may be prepared in the month of March, when plants shed most of their leaves. These cuttings are planted in nursery beds at a spacing of 30 cm x 30 cm or in polybags. Pre-treatment of stem cuttings with 300 ppm IBA (Indole butyric acid) solution for 5 minutes is desirable. Sprouting starts within 7 days of planting.

Plants propagated by cuttings will normally produce seeds within a year of planting and growth is rapid. However, it has been observed that seedlings raised from seeds have a better root system compared to pre-rooted cuttings, which develop secondary and tertiary fine roots. Such seedlings are more stable during storms. The plants raised through cuttings will be true to type and will have similar characteristics of the mother plant. To maintain the quality of plantations of Pongamia, there is a possibility of in situ grafting. The rootstock may be raised directly by seeding in the pits (two to three seeds). The desirable scion material may be grafted on the rootstock when the seedlings attain pencil thickness.

Wedge grafting has been found to be most successful using 3-month-old seedlings raised in polybags as the stock and semi-hardwood scions of 12 to 15 cm length.

The so called “Chinese Layering” is another effective method of vegetative propagation in *P. pinnata*, where roots are produced in small branches by applying root producing hormones and rooting media. The method can be employed to tertiary branches of Pongamia without much damage to the mother plant.

Cultural Operations

Planting

The field may be ploughed (deep tilled) followed by harrowing at the beginning of the rainy season or by utilizing off-season rains. Direct planting may be carried out in pits (60 cm x 60 cm x 60 cm) dug in

hilly and rocky areas where cultivation is not possible. Refilling the pits may be done with a mixture of 5 kg FYM, 50 g DAP and methyl parathion (2% dust) at 5 to 10 gm thimmet granules per pit (to protect young saplings from termites). One-year-old healthy seedlings are selected and uprooted with the ball of earth for transplanting in the field. The onset of the monsoon, i.e. June-July is the right time for plantation.

A spacing of 3m x 2m or 3m x 3m is desirable for inter-cropping and inter-cultivation. For Pongamia block-planting, a spacing of 2 m x 2 m or 5 m x 5 m or 6 m x 6 m may be used. For avenue and field boundary planting, a spacing of 2 m to 4 m may be used between plants. About 500 plants/ha at a spacing of 5 m x 4 m will produce the desired yields (Kesari and Rangan, 2010).

Irrigation once in a month during the dry period will enhance growth and productivity. Rainwater conservation techniques like planting on contour or staggered trenches will be advantageous in hilly, sloping and rocky areas where inter-cultivation and intercropping is not possible. Making ring basins around the plants and mulching (dust mulch/organic mulch) will conserve soil moisture and minimize irrigation needs. Tree lopping and straw is ideal for conserving the soil moisture in the basins. Creating surface roughness by inter-cultivation, etc. will enhance rainwater conservation and use.

Tending Operations

The basin should be kept free from weeds. Hoeing and weeding is essential during the establishment period. Around 2-3 weedings/ inter-cultivations are enough to keep the field free from weeds and conserve moisture.

The Pongamia plants may be pruned initially to give the stem a straight form and later lightly lopped for green leaf mulch. All the side branches of the trees, one-third from the bottom, may be pruned and the top two-third branches may be retained. Periodical pruning may be carried out depending upon the vegetative growth of the plants. The pruning should be done when trees shed leaves and enter into a period of dormancy. Diseased, dead, excessive, weak and lateral branches should be removed.

Tree Protection

Pests

Leaf miner (*Acrocercops anthrauris*), leaf galls and bark-eating caterpillar are the common pests of Pongamia. These pests may be controlled by spraying Endosulfan at 3 ml per litre of water. Monocrotophos 0.01% is also used for controlling leaf miner.

Microdiplosis pongamiae and *Myricomyia pongamiae* cause greenish, hollow, polypoid, pedicelled galls on the upper surface of leaflets starting with the new flush of leaves. Severe incidence can be controlled with foliar sprays of dimethoate 30 EC at 1 ml/l together with an acaricide, kelthane, at 3 ml/l, prior to the onset of new flush of leaves before the start of summer.

Both nymphs and adults suck the sap from the plant parts especially terminal twigs during summer causing drying up of growing shoots. Nymphs can be prevented from ascending the trunk by fastening a grease band on the trunks a few feet above the ground. Alkathene banding of 25 cm width around the trunk prevents crawlers infesting the shoots. Trunks sprayed with Neem seed kernel extract (4%) or Neem oil (0.3%) with surfactant (2.5ml/15l) can control crawlers.

Diseases

Leaf spot and blight caused by *Fusicladium pongamiae* lead to severe leaf deformities. Leaf blotch disease caused by the fungus *Microstroma pongamiae* is characterized by white to cream spots giving a yellowish appearance to the leaves. Rust caused by *Ravenelia hobsoni* leads to chestnut brown teliospore heads on the lower surface of leaves. Anthracnose caused by *Cercospora pongamiae* and *Sphaceloma pongamiae* results in spots on leaves, tender shoots and pods resulting in severe damage and defoliation in young seedlings and trees. In severe cases, disease control is achieved by foliar sprays of carbendazim 2 gm/l or dithane-Z-78 at 2g/l during July-September. Wettable sulphur at 1 gm/l can also check the foliar diseases.

Suitable Agroforestry Systems

Pongamia can be planted along boundaries or along the road at 5 m spacing. The crops like cowpea, cluster bean, dhaincha and mung are grown as intercrops in agri-silviculture agroforestry system in Haryana (Kaushik et al. 2016). In Gujarat, four *Ocimum* species were intercropped under 2.5 years old Pongamia- based agroforestry systems named as silvi-medicinal system (Pongamia+*Ocimum* spp.). Significantly higher fresh above- and below-ground and total herbage and oil yield of *Ocimum* spp. was recorded under silvi-medicinal systems compared to sole cropping. The findings suggested that higher fresh herbage and oil yield can be achieved under silvi-medicinal systems compared to sole cropping (Kumar et al. 2015).

Pongamia-based agroforestry system

Yield

A long rotation period of up to 50-60 years is used in Pongamia management. However, it may be managed by following 30 years rotations for fuelwood. Pongamia seed kernels have a good commercial value because of their high oil content, which ranges from 27 to 43% and is a viable source for expanding biofuel industry.

Trees often start bearing at age of 4-7 years. A medium-sized tree can yield 25- 40 kg of seed per year and, later, 50 kg per year. Seeds can be collected during April-June.

Utilization

Pongamia is a promising biodiesel tree species (Kesari and Rangan, 2010). The leaves can be used as fodder for cattle and goats, although this is not a common practice. The leaves contain 43% dry matter, 18% crude protein, 62% neutral detergent fibre, and in vitro dry-matter digestibility of 50%. The press cake (seed residue) after oil extraction is bitter and unfit for use as a sole animal feed. It is used in blending with nitrogenous fertilizers. With a calorific value of 4600 kcal/kg, the wood is commonly used as fuelwood. The timber is moderately strong and used for cabinet making, cartwheels, posts, agricultural implements, tool handles and combs. The wood ash is employed in dyeing. Oil from the seeds is used for leather dressing in tanning. The non-edible oil extracted from seeds has been traditionally used as fuel and lubricant and in soap making. It is also rubbed as liniment on skin diseases and rheumatic parts.

References

Kaushik, N., Deswal, R.P.S., Tikkoo, A., Kumari, S., Malik S. and Kumar, K. 2016. *Pongamia pinnata* L. (Karanja) based agri-silviculture system under rainfed conditions of south-west Haryana. *Journal of Applied and Natural Science* 8 (1): 31– 34.

Kesari, V. and Rangan, L. 2010. Development of *Pongamia pinnata* as an Alternative Biofuel Crop - Current Status and Scope of Plantations in India. *Journal of Crop Science and Biotechnology* 13 (3): 127- 137.

Kesari, V., Das, A. and Rangan, L. 2009. Physico-chemical characterization and microbial assay from seed oil of *Pongamia pinnata*, potential biofuel crop. *Biomass Bioenergy* 34: 108-115.

Kumar, A., Suvera, H., Thakur, N. S. and Jha, S. K. 2015. Herbage and essential oil yield of *Ocimum* spp. intercropped under *Pongamia pinnata* based silvi-medicinal systems in Gujarat, India. *The Bioscan* 10 (1): 81-85.

Chapter 21

Populus deltoides Bartr. ex Marsh.

Family: Salicaceae (willow family)
Common name: Poplar
Trade name: Eastern Cottonwood/poplar
Origin: Canada, United States of America

Botanical Characteters

Populus deltoides is a fast-growing, medium-sized to large tree, 20-30 m tall and 100 cm dbh (diameter at breast height). Bark is greyish-green and smooth at first, later blackish and furrowed; trunk short and massive in the open, often divided into a few large, wide-spreading limbs near the ground to form a broad, irregular- shaped, open crown. Leaves broadly deltoid, 8-15 cm long and nearly as broad, glabrous on both sides, short- acuminate, dentate, with incurved glandular or callous-tipped teeth; bases truncate to subcordate, with 2-3 basal glands; petiole strongly flattened laterally.

Bracts of catkins fringed or fimbriate, the divisions narrow; staminate aments 7.5-12.5 cm long, thick; stamens about 60 or more; anthers red; pistillate aments green and slender; ovaries glabrous; stigmas 3 or 4. Mature seed catkins 15-25 cm long; stalk hairless;

A mature Poplar tree

capsules ovoid, 6-10 mm long, glabrous, green, splitting into 3-4 parts when mature; peduncle 3-10 mm long; seeds cottony. *P. deltoides* is dioecious with sex ratio of 1:1. Male buds develop somewhat earlier than female buds and are much larger. Flowering occurs before leaves appear.

Distribution

P. deltoides is the most widely planted species of poplar in India. It was introduced in India in the late 1950s. It is planted in plains of North-West India, i.e., Western Uttar Pradesh, Punjab and Haryana and to some extent in the outer plains/valleys of Uttarakhand and Himachal Pradesh. It is widely planted in the Tarai belt extending up to Bihar and West Bengal

Silvicultural Requirements

P. deltoides generally requires sub-tropical climate, usually above 28 ^{o}N latitude. In India, poplars grow in areas having mean minimum and maximum temperature of 6 ^{o}C and 45 ^{o}C, respectively, and springs must be free from late frost.

It grows on a wide variety of soils, but performs best on deep, fertile, clayey loam, sandy loam, alluvial loamy soils rich in organic matter. Well drained soils having pH between 5.8 and 8.5 and adequate moisture are considered best for its growth. The sites having a slope less than 8% are considered ideal for raising poplar plantations. *P. deltoides* is very intolerant of shades, tolerates frost and waterlogging, but is susceptible to fire.

Phenology

P. deltoides is deciduous in nature. In India, leaf shedding occurs in October–November and foliage initiation in March–April. Flowering occurs in April and fruit set in June. It coppices well and produces suckers.

Poplar produces some seeds each year, but bumper crops occur at intervals of 3 to 5 years. Typically, the longevity of poplar seeds under natural conditions is quite short–about 2 to 4 weeks.

Under controlled low-temperature (-18 to 5 °C) and stable moisture content (5 to 8%) conditions, the seeds can be stored up to 140 days.

Propagation Technology

Through Seeds and Cuttings

Poplar is propagated through seeds, cuttings and tissue culture. The most deployed conventional propagation technology is stem cutting.

Cuttings should be taken during the dormant season when the trees are leafless. They may be taken from branches, epicormic shoots, but not from the crowns of older trees because such cuttings may produce curved boles or a branchy habit. The trees from which cuttings are taken should be completely healthy, as any disease present in the parent trees will be carried on to their offspring. Care should be taken to select parent trees of good bole form and rapid growth.

Cuttings should be planted directly where the trees are to be grown. However, for raising poplars on a commercial scale more elaborate nursery techniques are needed. Nursery seedlings are used to prepare cuttings. Cuttings should be prepared with a very sharp and fairly heavy tool to obtain a very clean and smooth cut The length of the cuttings should be around 20 to 22 cm and diameter 1 to 2 cm. Maximum number of available cuttings from each plant down to 1 cm diameter can be used for planting. Splitting of cuttings at the time of preparation should be avoided and no split cutting should be used for planting. All cuttings must be submerged under fresh water in drums immediately after their preparation.

Treat the cuttings with Aldrin as an anti-termite measure. Prepare an emulsion by thoroughly mixing 250 ml Aldrex 30 E.C. in 100 litre of water and soak the cuttings in this emulsion for 10 minutes. Thereafter, the cuttings should be treated with Emisan–an organmercurial fungicide (250 gm Emisan-6 in 100 litre water) and kept submerged for 10 minutes. Cuttings can be graded by their thickness and it will be useful to plant cuttings of more or less uniform thickness in a bed.

The best time for planting of cuttings is January–February.

Spacing for setting of cuttings in nursery beds should be 80 cm x 60 cm. Planting rods with the lower ends flattened and sharpened like a screw driver should be used for making the planting holes. Planting rods should have a ring of paint at 22 cm length from the bottom. The rod should be inserted at the point of the stake up to the paint mark. Each cutting with its thinner end up should be planted in the hole in such a way that the upper portion is just 2 cm above the ground. After planting, the soil around each cutting should be compacted gently but firmly without injuring the bark of the cutting, and drenched with Aldrex emulsion immediately.

Irrigation should be provided as soon as the planting of cuttings is completed. The first irrigation should be such that about 5 to 7 cm water is uniformly above ground level. Subsequent irrigation should be light and the interval may vary between 7 and 10 days depending upon the type of soil.

Cultural Operations

Planting

Selection of proper sites for poplar plantations is of utmost importance because survival and growth rates of plants depend largely on the site quality. Low-lying areas subject to accumulation of water during rains should be avoided.

January–February is the best period for transplanting poplars from nursery to the field in northern India. Digging of pits in the preplanned irrigation channels after proper alignment should be completed before obtaining the plants from nursery. The depth of the pits should be 1 m from bottom of the irrigation channel. These pits are made with specially designed hand augers which will give 15 cm diameter or with a tractor-mounted auger. Square as well as rectangular planting methods are adopted for raising poplar plantations. The common spacings adopted for poplar plantations are: 5 m x 5 m, 4 m x 5 m, 5 m x 4 m, 7 m x 3.5 m, 8 m x 2.5m.

Entire tree planting (ETP) is commonly followed in India for poplar planting in field. One-year-old nursery plants, 3 to 4 m in height, with naked roots, called “entire transplants” are used

for transplanting in the field. Nursery beds should be given a light irrigation 7-10 days before uprooting. Very tall plants are undesirable for warmer climate, because they take long time to sprout and generally sprout from bottom. The apical bud of nursery plants is highly cutinised, as such, it opens only when suitable temperature is there to melt wax. Hence, it is advocated to remove apical 30-40 cm length of nursery plant over a healthy bud prior to planting out, by giving a clean circular cut. A circular cut has the advantage of minimum cut surface and smaller area for healing. A plant between 3 and 4 m in height is the best to be planted out. The height-diameter ratio at collar point should be closest to 100, i.e. the diameter should be 3 to 4 cm corresponding to height. Long distance transport and exposure to sun should be avoided. It is better to plant out within 48 hours of uprooting from nursery and, prior to planting out, plants be immersed in fresh, clean water for 12 to 24 hours, so they are fully charged with moisture.

Pits having 1 m depth and 15 cm diameter are made with the help of an auger. The seedlings are planted straight in the holes

Distribution of poplar ETPs to village heads, and planting in farmers' field by ICAR-CAFRI researchers at Muzzafarnagar, U.P., India

and a mixture of top soil, 2 kg FYM, 50 gm SSP, and 25 gm MOP is filled and packed with hands. The upper 10 cm of pits should be left unfilled to give maximum advantage of irrigation water to the seedlings.

The application of fertilizers/manures depends on the fertility status of the land. The general schedule of application of fertilizers/manures is given below:

Year*	FYM (kg/plant)	Urea (gm/plant)	SSP (gm/plant)
First	5-8	50	50
Second	10	100	100
Third	10-12	120	120
Fourth	15	150	150
5-8 years	15	200-250	

*Period: June to August

Application of fertilizer must be followed by light irrigation. If the soils are deficient in zinc, zinc sulphate at 25 kg/ha should be applied.

Tending Operations

During the first year of plantation, two manual weedings are recommended. Hand weeding by pulling or string trimmer may be done if the area is small. Debudding should be carried out in the lowest one-third of the stem in May and June. Removal of co-leader should also be carried out simultaneously and repeated after completion of 2 years of growth. At the age of 2-3 years, the lower one-third, and of 4-5 years the lower one-half, of the tree should be pruned. Excessive pruning may lead to development of vigorous epicormic branches and retard diameter growth. After first year, pruning and leader training should be carried out only during winter. Bordeaux paste must be applied immediately after carrying out pruning/leader training.

After 3 years, thinning may be done based on market price. Pulp industry requires 3- to 4-year-old trees, so alternate thinning can be carried out to obtain good-size trees for plywood industries.

Tree Protection

In India, poplars are prone to over 143 fungal, bacterial, and viral pathogens, which cause considerable damage to leaves, branches, boles and roots. One of the major threats to commercial poplar plantations is the stem borer, *Apriona cinerea.* The most common insect-pests and their management is given in Table 1, and diseases and their management in Table 2.

Table 1. Important insect-pests of *P. deltoides* and their management in north-western India (Singh et al. 2004)

Sr No.	Insect	Nature of damage	Management
a) Nursery Pests			
1	Poplar Shoot Borer– *Eucosma glaciata*	Larvae borer of green shoots leading to drying of shoot tips	Foliar spray of dimethoate (0.02–0.04%) in May–June Monthly soil application of Aldicarb (20-40 g/sq m) or carbofuran (3G) at the rate of 10 gm/sq m from April to September
2	Leopard Butterfly- *Phalantha phalantha*	Larvae defoliator of leader shoots and young leaves	Methanol extract of *Azadirachta indica* seed kernel, e.g., nemol or nemidine at 0.125% and 0.025% dilution
3	Poplar leaf Beetle – *Nodostoma waterhousie*	Larvae and beetle both defoliate	Foliar spray of carbaryl (0.2%) or malathion (0.1-0.2%)
4	White grubs– *Holotrichia* sp., *Granida* spp., *Brhamina* sp.	Beetle feeds on the leaves while the grub debarks and cuts the roots of cuttings and young plants	Clean cultivation and deep ploughing is recommended. Application of chlorpyriphos (0.2%) or phorate (10 gm) at 200 gm/10 sq m during May-June in nursery beds after soil working is advisable. Foliar spray with carbaryl (0.2%) twice at weekly intervals is effective against the defoliating beetles

b) Plantation Pests			
5/6	Poplar defoliators- *Clostera cupreata* Butler and *Clostera fulgurita* Walker	Larvae are defoliators	Genus-specific Nuclear Polyhedrosis Virus (NPV), a *Baculovirus* of subgroup A, infects and kills *Clostera fulgurita* populations. Spraying of malathion (0.2%) or cypermethrin (0.001%) in water also gives effective control
7	Looper– *Ascostis selenaria*	Larvae are defoliators	Spray methyl-demeton (0.02%) or dimethoate (0.02%) or Monocrtophos (0.02%) when new flush of leaves come in spring (March)
8	Poplar stem borer –*Apriona cinerea*	Larvae borer of xylem in stems, trunk, roots of standing trees	Inject 5 ml fumigant (saturated solution of para-di-chloro-benzene in kerosene oil or carbon disulphide) using a syringe in lowest ejection hole made by the grub in the bole and then plug the holes with moist clay
C) Termites			
9	*Coptotermis heimi*	Girdles root/shoot of cuttings and heart wood of plants up to 3 m above the ground	Chlorpyriphos (0.2%) or Endosulfan (0.2%) in water solution or their dust applied around the tree trunks during summer (June) is effective.
10	*Odontotermis distans*	Attacks heart wood from the ground or through injuries in the stem near the ground	

Table 2. Important diseases of *P. deltoides* and their management in north-western India (Singh and Singh, 1986)

Sr No.	Disease	Management
1	*C. salmonicolor*	0.2% Dithane-M-45 + 0.1% Bavistin (spray)
2	*M. ciliata*	Copper oxychloride (0.2%)/fortnight; Bavistin (0.1%) or combinations of calixin (0.075%) + Dithane-M-45 (0.15%) /three sprays/20 days intervals; 0.1% Bavistin; Nurseries/ six sprays/ fort night/Bavistin 0.1% spray at fortnightly interval Cyproconazole(0.03%) or Triadimefon (0.05%) at two weeks intervals; Penconazole best (35.48% disease)
3	*R. solani*	Blitox, Captan and Thiram at 20-50gm/m^2 (drenching)
4	*C. humile*	0.4% Dithane-M-45 (spray);

Suitable Agroforestry Systems

Cultivation of *P. deltoides* in agroforestry systems by farmers started in the 1970s. Initially it was grown only by rich and progressive farmers who had surplus land and financial capacity to take the risk of plantation failure. The credit for taking this tree to farmers for widespread plantation goes to WIMCO that started an extension project for massive plantation of poplar in Punjab, Haryana and western Uttar Pradesh with financial support from the National Bank for Agriculture and Rural Development (NABARD). The WIMCO-NABARD poplar scheme has been a noble venture of partnership between industry and the banking sector for the benefit of the farming community, industry and the unemployed, besides providing environmental services. Poplar has become the most preferred tree species for commercial agroforestry systems in north-western states. *P. deltoides* is the only species of polar that is planted on a significant scale in India. It constitutes the backbone of agroforestry in irrigated plains of Northern India. Clones: G-48, Udai, W-22, W-32, W-39, A-26, S-7 C-15, S-7 C-8 are suitable for agroforestry. When poplar is planted on field boundaries, kharif as well as rabi crops can be grown in the field throughout the rotation of poplar. In block plantation of poplar, the usual kharif crops can be grown for two years only; thereafter, shade-bearing crops like

First year

Second year

Third year

Fourth and Fifth year

Poplar agroforestry systems at different ages

ginger, turmeric, etc . are planted. However, rabi crops can be grown as usual. Poplars also serve as a windbreak. Intercropping is almost always preferred as it provides agricultural returns on the one hand and increased growth of poplar on the other due to frequent irrigation and hoeing of agricultural crops. Agricultural crops such as wheat, mustard, turmeric, ginger, colocasia, cabbage, potato, spinach, garlic, etc. and fruit crops such as citrus, guava, mango, etc. can be profitably grown with poplar (Sharma, 1996). Poplar–wheat and poplar–mustard are the most common combinations under agri-silviculture systems in Punjab.

Paired row poplar (G 48) agroforestry system (18 m x 2 m x 1 m)–1.5 years old– at Rasulpur-Jattan, Muzzafarnagar, U.P., India

Yield

Poplars can produce moderate quality veneer logs at short rotation periods of 6 to 8 years, achieving a high productivity of 20-25 cu m/ha/yr. In India, *P. deltoides* is usually harvested at a target diameter of 24 cm dbh. The productivity of well-managed poplar plantations under Punjab conditions is estimated to be 46.92 cu m/ha/yr, whereas the average productivity of natural forests in India is only 0.7 cu m/ha/yr (Verma, 1993).

Utilization

Exotic poplars were initially introduced in India to meet the needs of match industry. Later, poplar wood began to be used extensively in making plywood. Poplar veneers are not suitable for classification as Type A surface (Bansal, 1999). Hence, poplar veneers in plywood industry are used only as core and cross band veneers. The earliest contribution of poplar trees to the farmers was as fuelwood from pruning. It is also used in packing cases for fruits and other food stuffs. It is also an excellent source of fibre for various grades of paper (fine paper, packing paper and newsprint).

References

Bansal, A. K., Narayanprasad, T. N. and Mathews, K. C. 1999. Plywood from plantation species–*Populus deltoides* (poplar). Paper presented at the National Seminar on Poplar at FRI, Dehradun. Nov. 25- 27, 1999.

Sharma, K.K. 1996. Agroforestry in farming systems development. *Indian Forester* 122(7): 547- 559.

Singh, A P., Bhandari, R.S. and Verma, T.D. 2004. Important insect pests of poplars in agroforestry and strategies for their management in northwestern India. *Agroforestry Systems* 63: 15–26.

Singh, P. and Singh, S. 1986. Insect-pests and diseases of poplars. Dehradun, Forest Research Institute. 74 pp.

Verma R. K. 1993. Studies on growth and performance of *Populus deltoides* Bartr. in Punjab. M.Sc. Forestry Thesis. Punjab Agricultural University, Ludhiana: 154 pp.

Chapter 22

Prosopis cineraria (L.) Druce

Family: Leguminosae; **Sub-family:**Mimosoideae
Common name: Khejri (also Khejadi), King of Desert
Trade name: Khejri or Khejadi
Origin: Afghanistan, India, Iran, Pakistan,Sri Lanka

Botanical Characters

Prosopis cineraria is a medium-sized evergreen tree which attains a height of 4 to 9 m after 10 to 15 years and forms an open crown. The stem is usually straight with a grey roughish bark, exfoliated in numerous thin flakes. The branches are slender with small compressed, straight and scattered thorns of 3-6 mm length. The leaves are 2.5-8.0 cm long, bipinnate usually with two pairs of pinnae and 7-14 pairs of leaflets. Inflorescence is raceme. Flowers are small, cream-yellow, axillary and in spikes of 7 to 11 cm length. Pods are cylindrical and seeds are embedded in brown pulp. Seeds are longitudinal ovate and dull brown in colour.

***Prosopis cineraria* in the desert of Jaisalmer, Rajasthan, India**

Distribution

P. cineraria grows in dry tropical forests and tropical thorny forests. It is essentially a tree of plains, gently undulating ground and ravine land, seldom extending into hills,

mostly confined to 50–800 m altitude. It is recognized as one of the important tree species suited to arid and semi-arid regions for fuelwood, timber and forage in plantations as well as agroforestry systems (Kaushik and Kumar, 2003).

It is distributed in India, Afghanistan, Pakistan, Iran, Saudi Arabia, the United Arab Emirates and Yemen. It is commonly found in the Thar Desert of India and Pakistan. In India, it is found in arid and semi-arid parts of Rajasthan, Gujarat, Haryana, Punjab, Maharashtra, Karnataka and Andhra Pradesh.

Silvicultural Requirements

The tree is a light demander and the older plants are drought resistant. It can withstand extremes of temperature up to 50 °C and less than 100 mm rainfall. It is found growing in areas with as little as 75 mm of annual rainfall (but generally 150-400 mm) with dry seasons of eight months or more. It is slightly frost-hardy. The tree is found in alluvial, coarse, and sandy, often alkaline soils where the pH may reach up to 9.8. It is also common on moderately saline soils, but it quickly dries out where the soil is very saline.

Phenology

The tree starts flowering and fruiting at an early age. Five years old coppice shoots produce as fertile seed as the older trees. New leaves appear before or simultaneously with the fall of the old ones in summer. The flowering takes place during February and March, and the seed matures during April to June. The seeds mature earlier in southern than in northern states. They are dispersed by wind and animals.

Propagation Technology

Through Seeds

A fair amount of seed is produced every year, which remains viable for a long period in dry storage. The pods are collected during April-June from the best trees, kept for sun drying for a few days and then threshed for seed extraction. Trampling with feet, tossing around or beating the pods inside a sack are the methods used for seed

separation. Seeds may be cleaned by blowing or winnowing. Store the mature, healthy and well dried seeds in dry, cool environment at sub-freezing temperature.

The seeds can be directly sown in polythene bags during February to March and September to October. The bags should be filled with sandy loam soil mixed with compost in the ratio of 2:1. Soaking the seeds in cold water for 72 hours or mechanical breaking of seed coat or acid scarification for 5 to 15 minutes is recommended for better seed germination. Germination up to 86.6% was reported after 15 days with seeds soaked in water at room temperature for 72 hours (Puri and Kumar, 1995). One to two healthy seeds should be sown at a depth of 3-5 cm. Until germination is completed, mild irrigation may be carried out daily. Generally, germination is completed within 15 days.

Seeds can be sown directly during the rainy season in nursery beds at a depth of 3-5 cm. About 80 to 90% germination can be achieved. Seeds sown in March produce transplantable seedlings after six months, and October-sown seeds produce seedlings which are ready for transplanting after nine months.

Vegetative Propagation

P. cineraria is difficult to propagate by cuttings, although treatment with rooting hormones has proved successful in India. It can be propagated vegetatively from stem cuttings of juvenile material (Arya et al. 1993). It can also be propagated through air layering (Solanki et al. 1986). Twigs of 10-15 mm diameter, treated with Seradix B3 and covered with clay in July or August, gave 100% rooting success. It is recommended that layers are started in July, detached from the tree in September and planted out in November.

Cultural Operations

Planting

Pits of 45 cm x 45 cm x 45 cm or 60 cm x 60 cm x 60 cm are dug in April and May. The soil is allowed to dry for some time and pits

are then refilled with a mixture of 1 or 2 kg of FYM per pit. About 20 gm of zinc sulphate and 10 gm of benzene hexachloride powder is also added into the filling mixture. The seedlings are transplanted during the monsoon season. After planting, four irrigations are given at an interval of 4 to 5 days during the first month. Water harvesting structures are made immediately after planting for conservation of rain water. Development of micro-catchment areas, half moons, and ridge and furrow system for moisture conservation are suitable techniques to establish better agroforestry plantations. The ridge and furrow method of water harvesting was found to be the best treatment (Gupta, 1994). The seedlings are sensitive to frost and drought up to an age of two years; therefore, young plants must be protected from frost during winter and heat waves during summer. Block plantation may be carried out at 5 m x 5 m spacing or 3 m x 5 m spacing. A wider spacing of 10 m x 10 m or 15 m x 10 m is used for agroforestry plantations.

Tending Operations

The weeding and soil working by manually ploughing to a depth of 10 cm should be carried out at 3-month intervals for better establishment. During initial years, pruning is carried out to obtain

Prosopis cineraria **polarded**

unforked/unbranched straight boles for timber and to carry out agricultural operations smoothly. The pruning should be done from the first to the third year of establishment. Generally, pruning is carried out with lopping in winter of every year. All side branches of the tree should be removed up to 1 m of stem height in the first year, and up to 2 m stem height in the second year. As a rule of thumb, about one-third of the stem above ground should be kept branch free.

Farmers usually lop their trees in winter every year. Lopping starts in mid-November and continues up to January. Older twigs and branches are removed and 1-2 years old branches are retained for making canopy. The tallest branch of one or two years old is left with some foliage which serves as flag for the tree. Early pruning to encourage straight growth is recommended (NAS, 1980).

Tree Protection

Four species of long horned beetles, namely, *Derolus iranensis* (=descicollis) Pic, *Aeolesthes holosericea* Fab, *Hypoeschrus indicus* Gahan and *Acanthophorus serraticornis* (Oliver) have been recorded to cause severe damage to *P. cineraria* in four north-western districts of Rajasthan (Ahmed et al. 2004). Coleopteran larvae of stem and root borer, *Celosterna scabrator*, bores the living stems and roots of *Prosopis* sp., and *Laccifer lacca* feeds on the cell sap of branches. Leaf gall by *Contarinia prosopidis* and *Eurotoma* sp. cause 25-30% fodder loss. Gall midge can be controlled by spraying the infested trees with 0.15% carbaryl or 0.08% Endosulfan at seven days intervals.

Suitable Agroforestry Systems

P. cineraria is one of the best agroforestry tree species for dry areas and deserts, as new foliar growth, flowering and fruiting occur during extreme dry months (March–June) when most other trees of the desert remain leafless or dormant. Because of its multiple economic value and suitability in agroforestry systems, it is conserved in arable land. A higher yield of grasses has been observed when grown in combination with this tree (Shankar and Saxena, 1976).

***Prosopis cineraria* with mustard in Pali district of Rajasthan, India**

***Prosopis cineraria* with cluster bean in Jodhpur district of Rajasthan**

It has also been reported that the canopy of this tree has a boosting effect on herbage yield, growth and botanical composition of natural pastures (Shankar et al. 1976). Khejri+mustard and khejri+cluster bean combinations are also observed in various parts of Rajasthan.

Yield

The trees reach 3-5 m height in 5-6 years with an average diameter of 6 cm. Annual firewood yields of up to 2.9 cu m/ha have been reported (NAS, 1980). A moderate sized tree may yield 45 kg of dry leaf fodder per year. Normally, healthy trees produce 4-5 kg pods per tree per year. In eight years old plantation of *P. cineraria* at a spacing of 4 m x 3 m about 21-32 t/ha of utilizable biomass has

been reported. Singh and Bishnoi (2014) suggested that the fodder yield of *P. cineraria* was generally more from trees that are lopped annually than from those lopped once in two years or once in three years. It was also reported that the yield of forage increases as the tree girth increases. Similarly, fuelwood yield was also more in annually lopped treatment than in lopping treatments done once in two or three years.

Utilization

P. cineraria pods are used as a vegetable both in dried and green forms in many parts of the Thar desert in India. The tree provides fodder during the extremely dry summer months when most other trees are leafless. Its pods, containing a dry sweet pulp, also provide good fodder. It is an excellent fuel, also giving high-quality charcoal (5,000 kcal/kg). Its wood is used for boat frames, houses, posts, and tool handles. The trees are planted for sand dune stabilization and reclamation. It also fixes atmospheric nitrogen.

References

Ahmed, S. I., Chaudhuri, K.K., Sharma, M. and Kumar, S. 2004. New insect pest records of Khejari and Rohira from Rajasthan and their possible management strategies *Indian Forester* 130, 1361-1374.

Arya, S., Toky, O.P., Tomar, R., Singh, L. and Harris, P.J.C. 1993. Seasonal variation in auxin-induced rooting of *Prosopis cineraria* (L.) Druce stem cuttings. *The International Tree Crops Journal* 7: 249-259.

Gupta, G.N. 1994. Rain-water management for tree planting in the Indian Desert. *Journal of Arid Environments* 31(2): 219–235.

Kaushik, N. and Kumar, V. 2003. Khejri (*Prosopis cineraria)* based agroforestry system for arid Haryana. *Journal of Arid Environments* 55(2): 218-221.

NAS (National Academy of Sciences). 1980. Firewood Crops. Vol. 1. National Academy Press, Washington, D.C. pp 150- 151.

Puri S. and Kumar, K. 1995. Establishment of *Prosopis cineraria* (L.) Druce in the hot desert of India. *New Forests* 9: 21–33.

Shankar, V. and Saxena, S.K. 1976. Khejri–the tree that boosts grass yield. *Indian Farming* 26:22.

Shankar, V., Dadhich, N. K. and Saxena, S.K. 1976. Effect of khejri tree (*Prosopis cineraria*) on the productivity of range grasses growing in the vicinity. *Forage Research* 2:91-96.

Singh, J. and Bishnoi, M. 2014. Effect of lopping intensities on fodder and fuelwood yield of *Prosopis cineraria* in arid zones of Thar. *Academia Arena,* 6(10): 90-94.

Solanki, K. R., Kackar, N. L. and Jindal, S. K. 1986. Air layering in *Prosopis cineraria* (L.) MacBride. *Indian Forester* 112 (3): 202-207.

Chapter 23

Salix alba L.

Family: Salicaceae
Common name: White Willow
Trade name: Willow
Origin: Europe and Western and Central Asia

Botanical Characters

Salix alba is a medium-sized to large deciduous tree growing up to 10–30 m tall, with a trunk up to 1 m diameter and an irregular, often-leaning crown. The bark is grey-brown, and deeply fissured in older trees. The shoots in the typical species are grey-brown to green-brown. The leaves are paler than most other willows, due to a covering of very fine, silky white hairs, in particular on the underside; they are 5–10 cm long and 0.5–1.5 cm wide. The flowers are produced in catkins in early spring, and pollinated by insects. It is dioecious, with male and female catkins on separate trees; the male catkins are 4–5 cm long, the female catkins 3–4 cm long at pollination, lengthening as the fruit matures. When mature in mid-summer, the

A *Salix alba* tree

female catkins comprise numerous small (4 mm) capsules, each containing numerous minute seeds embedded in white down, which aids wind dispersal (Rushforth, 1999).

Distribution

S. alba was introduced from Europe in the Kashmir valley in 1916-17 for production of wood for cricket bats and is now cultivated in a number of other places. In general, the willows in India are confined primarily to the hilly regions, suitable for alluvial soils and nambal areas where submergence in water occurs for a major part of the year (9-10 months) but not during winter.

Silvicultural Rquirements

Willow exhibits different moisture requirements during different stages of its development and growth. The water consumption of this species is high and an annual rainfall of 600–1000 mm is considered ideal for its normal growth. It grows up to 2500 msl and has a height of about 30 m and girth 1 to 2 m.

The natural habitat of Salix is sandy alluvial and/or sandy loam soil with a lot of moisture. Some of its species also grow in swampy locations having clay soil. The stands growing in dry pockets, however, put on slow growth and also tend to become stunted. It can grow on slopes up to 33° near streams. Salix species are tolerant to flooding and flourish in saturated soils. It is a light demander and can adapt to fire regimes. Frost hardy and sensitive to drought, the species coppices and pollards very well.

Phenology

Old leaves are shed during autumn. New leaves appear during February-March. Flowering also occurs nearly simultaneously during March-April. The flowers are dioecious. Both male and female flowers are borne on terminal catkins. The fruits appear during May-June. These are 5 cm to 10 cm long. The bark, nearly 1 cm thick, is grayish (dark) with criss-cross fissures.

Propagation Technology

Through Seeds

Willows come up naturally from seed drifting/floating along river banks, stream beds, depressions and bunds of agricultural paddy fields having lot of water/moisture content. The species can be easily raised artificially from cuttings and sets.

Willows have high annual seed production and an effective system of seed dispersal which increases their chances of reaching different destinations for germination and establishment.

Vegetative Propagation

Propagation is generally carried out by planting sets or shoot cuttings of various sizes from December to March, depending on the local weather. Shoot cuttings of 90 to 120 cm length and 3 to 5 cm thickness are taken from healthy branches of mature trees and cut obliquely at each end. They are planted in nursery beds, with a spacing of 90 cm x 60 cm in holes made with a crowbar. The cuttings are set 60 to 90 cm deep in the soil. The sets must be in upright position. One-year old nursery-raised cuttings are used for planting in field. The shoots are grown into sets of 5 to 8 cm diameter at the lower end with a height of about 2.5 to 3 meters. Often, willows are planted in irrigated plantations. Regular irrigated channels of about 0.3 m x 2 m cross-section are prepared at the planting site 6 m to 4.5 m apart. Sets are planted in February-March in 40 to 60 cm deep pits in the prepared channels in a triangular pattern (Kaushik, 1961).

Cultural Operations

Planting

The field is prepared in January by removing debris, boulders and shrubby growth. On hard soils, pits of 45 cm x 45 cm x 60 cm size are dug open. In case of unrooted cuttings of willow, a hole, not exceeding 22 cm, is made at the bottom of the pit and the cutting inserted into it before refilling the pit to give additional anchorage

to the plant. On fresh level deposits (marshy silted upland) crowbar planting is done and a 60 cm hole is made by driving a stake in the ground. The set is then placed in the hole without damaging the bark and the ground tamped.

Direct planting of poles is a traditional method of raising cricket bat willow locally known as Mawas in Kashmir. The poles of 3 m long and approximate diameter of 30 mm at the top and 55 mm at base are selected from the pollarded willow for direct planting at the plantation site. The poles should be freshly cut, straight, well grown with suitable diameter and without knots.

The best time for planting is February-March, when the soil moisture is high. The bark should be protected from injury during transportation. The nursery-raised seedlings/poles can be planted in holes made with an auger or a crowbar or post hole bore at the depth of 70-90 cm for proper anchoring. Before planting, slice the lower part of the sets at an angle of 40-50° so it can absorb water. The planting site should have enough water available. The sets are planted at 3 m x 3 m or 4 m x 5 m spacing in an agroforestry system but in high density plantings the spacing is 1.5 m x 1.5 m or 2 m x 2 m.

Tending Operations

Pollarding is a common tending practice adopted in different Salix species. Generally, it is pollarded for fuelwood and fodder. The first pollarding of the planted willows is done after 3-4 years. Pollarding is done in winter during November-December at a height of 2.5 m above ground level. Four to five coppices are left on top of the main trunk. These are harvested later, during March-April, for raising new plantations. The annual pruning of the branches on the lower part of the trunk is also done during summer. Smaller twigs are separated for fodder, and thicker branches are kept for fuelwood. Once a tree develops a large head (the apical part of the trunk where coppices emerge), only very few coppices are produced. After 10–15 years of pollarding, the large head is removed in February–March for use as fuelwood. A large head not only produces very few coppices, which dry quickly, but also accumulates much snow and, thereby, becomes prone to uprooting.

The long sets need stacking after planting in open area. Stacking permits the sets or poles to withstand blowing winds, rainfall or snowfall. If poles are of more than 3-4 m height, two low size stacks will be needed. The sets/poles and stack are tied loosely to accommodate growth and not cause bark damage.

Removal of epicormic branches, when necessary, reduces chances of knot formation in wood and also maintains their commercial value for the bat industry. The tending operation is carried out up to a height of 200-250 cm. Generally, the first 5 years from planting are crucial to maintain quality.

Trunk height of 2 m to 2.5 m was most appropriate for pollarding of willow in cold desert environment of the Lahaul valley. Rawat et al. (2010) reported that while raising willow plantation, larger tree trunks of 2 to 2.5 m height and 3 years pollarding interval should be considered for better foliage and woody biomass production.

The willows are extensively browsed and, hence, young plantation should be protected at least for two growing seasons. Local farmers wrap the sets with cloth or plastic paper.

Tree Protection

Leaf rust of willow is caused by fungi belonging to the genus *Melampsora* (Uredinales: Melampsoraceae). Severe infestations can result in defoliation and premature leaf senescence, and significant reductions in biomass. Severe reductions in yield can be avoided by planting mixtures of willow clones that differ in resistance to *Melampsora* spp. rust. Fungicides such as triadimefon or mancozeb are also effective in protecting willow against rust.

Black canker caused by *Glomerella cinguilata* may kill the tree by repeated infections. It can be controlled to some extent by pruning in early spring and disposing of infected wood. Several species of aphids infest the willows. These may be controlled by spraying the tree with Malathion.

Crown gall caused by *Agrobacterium tumefaciens* results in irregular swellings at the base of the trees or on roots of nursery trees. It is very difficult to control this problem.

Suitable Agroforestry Systems

In the Lahaul and Spiti district of Himachal Pradesh, the various tree-crop combinations observed are: peas/potato/rajma/cauliflower + Salix, grasses+Salix/Eucalyptus and peas+Salix+grasses (Kumari et al. 2008). In Kashmir, various vegetable crops are intercropped with Salix plantations. Instead of pure plantation, Mir and Khan (2008) recommended the *Salix alba+Brassica oleracea* var. acephala and *Salix alba+Brassica oleracea* var. caularapa tree-crop combinations for adoption by farmers in Srinagar.

Yield

In Kashmir, an 18-year old tree with a 3 m clear bole of 1.2-1.8 m diameter is considered suitable for harvesting and can fetch Rs 5000-7000 per tree. The rotation cycle of commercially grown trees is 15 to 20 years. The average fuelwood production in the case of *S. alba* was reported to be 150-250 kg/tree. The bark of *S. alba* as well as its tender twigs are also harvested and on an average 15-25 kg of bark/twigs can be obtained from a middle-aged tree during a season. *S. alba* is a major contributor of fuelwood and fodder under the agroforestry system in the Lahaul valley of Himachal Pradesh.

Utilization

S. alba is extensively used for making cricket bats in India. Its wood is used for making fruit boxes (particularly apples) in Kashmir valley. It is also used for construction material, sweat lodges, furniture, baskets, splint of match boxes, and agricultural implements, etc. (Mir and Khan, 2008). It is also suitable for making paper pulp and charcoal. Tender twigs are lopped for fodder for goats and sheep. The willow trees are also very effective as windbreak strips for the agricultural crops.

References

Kaushik, R.C. 1961. Irrigated plantations of cricket bat willow (*Salix caerulea*) in Punjab. *In:* Proc.Tenth Silvic. Conf., Dehradun. pp 413-18.

Kumari, A., Sehgal, R. N. and Kumar, S. 2008. Traditional agroforestry systems practiced in Lahaul (Lahaul & Spiti) and Kinnaur districts of Himachal Pradesh. *Indian Forester* 134: 1003-1010.

Mir, A. H. and Khan, M. A. 2008. Projected benefit-cost analysis of agri-silvicultural system: vegetable crops intercropping with *Salix alba* (Willow). *Journal of Forestry Research* 19 (4):335−339.

Rawat, Y.S., Vishvakarma, S.C.R., Oinam, S.S., Todaria, N.P. and Maikhuri, R. K. 2010. *Salix fragilis* L.: Pollarding potential in dry temperate environment of the North-Western Himalaya, India. *Range Management & Agroforestry* 31 (1):1-6.

Rushforth, K. 1999. Trees of Britain and Europe. Collins. ISBN 0-00-220013-9.

Chapter 24

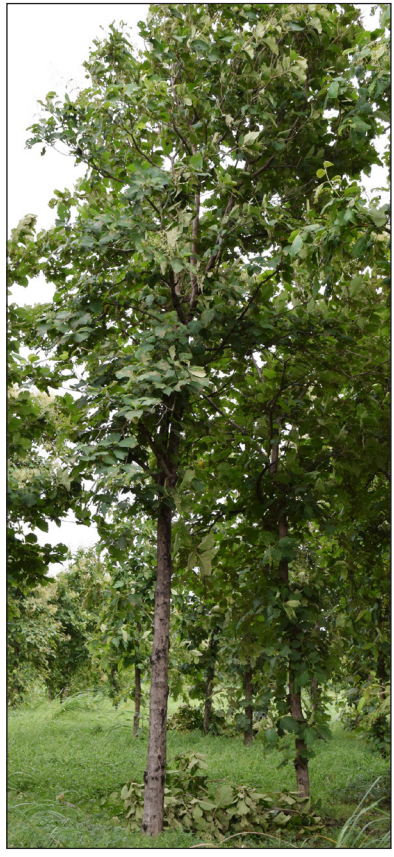
Tectona grandis Linn.f.

Family: Verbenaceae
Common name: Sagaun, Teak, Tega
Trade name: Teak
Origin: Native to India, Burma, Thailand

Botanical Characters

Tectona grandis is a large deciduous tree up to 30 m high and 100 cm or more diameter at breast height (dbh). The tree grows straight and stem is buttressed at the base. The leaves are opposite about 0.5 m long and 23 cm wide. The branches terminate in many small white flowers in large, erect, cross-branched panicles. The fruit is a drupe (fleshy, with a stony seed), two-thirds of an inch

Flowers and fruits of teak tree



***Tectona grandis* teak trees**

in diameter. The bark of the stem is about 1.3 cm thick, gray or brownish gray. The unseasoned heartwood has a pleasant and strong aromatic fragrance and a beautiful golden-yellow colour, which on seasoning darkens into brown, mottled with darker streaks. The timber retains its aromatic fragrance to a great age (Tiwari, 1992).

Distribution

Teak is indigeneous to the Indian Peninsula. It occurs in Madhya Pradesh, Uttar Pradesh, Gujarat, Maharastra, Kerala, Tamil Nadu, Karnataka. It is introduced in moist deciduous forests of West Bengal, Assam, Bihar, Uttar Pradesh, Orissa, and the Andamans.

Silviculture Requirements

Teak grows and develops well in low-altitude, high-rainfall areas and in climates that have a three to four months dry season. The hotter and wetter the season, the better. It prefers deep, fertile, and well- drained soils. Teak thrives best on soils that are slightly acidic or slightly alkaline. Soils that are rich in iron and aluminum lead to stunted growth. The sandy soil is best for this tree. It is a calcareous species (requires soils rich in calcium). The tree can grow at a maximum temperature range of 39-44 ^{o}C and a minimum of 13–17 ^{o}C. It grows well in rainfall zone of 1200-2500 mm. It fails to grow in soils with pH below 6.5.

Silvicultural Characters

Teak seedlings are sensitive to frost and drought. It is a strong light demander, intolerant of suppression and weeds. It is fire resistant. Seedlings and saplings are killed by fire and frost. It coppices and pollards vigorously.

Phenology

Leaf shedding occurs in November, December or in early January in dry and hot situations. New foliage appears in May. Teak seeds almost every year. Flowers appear during rainy season in June-September. The fruits ripen during November–January.

Propagation Technology

Through Seeds

The fruits are hard and seed coat needs to be treated to hasten germination. The seeds are pre-treated with hot water, alternate wetting and drying, immersion in cold water for several days, weathering and acid treatment to achieve good germination. The germination percent may vary from 10 to 70. Use of large seeds more than 14 mm in diameter gives better germination. Seeds are sown at 1 kg/sq m on raised nursery beds 10 m long, 1 m wide and 0.5 m in height, and covered with soil to a depth equivalent to the fruit diameter. Germination commences in about 15 days, accelerates during the next 15 days, but declines thereafter. Majority of germinates will have appeared in 40 days, when the germinability is around 40%. The beds are watered twice daily for the first two months, once daily for the next three months, and on alternate days thereafter.

Vegetative Propagation

Stumps

Stumps are prepared by cutting away from the seedling everything except 2.5 cm of the shoot and 22.5 cm of the root. The stem portion receives an oblique cut and the root portion a horizontal cut. All laterals from the tap root are pruned away. The stumps should preferably be planted within 2 to 3 days.

Cultural Operations

Planting

The land should be ploughed thoroughly and pits of size 45 cm x 45 cm x 45 cm prepared. The planting spacing should be 2 m x 2 m or 3 m x 3 m or 3 m x 4 m. Pits are filled with a mixture of farmyard manure and soil. Seedlings are planted in the pits during

rainy season. For stump planting a crowbar may be used. In the initial stages the plants have to be irrigated once a week and regular weeding has to be done. Irrigation helps reduce the rotation period and enhance productivity.

Tending Operations

Teak can withstand a certain amount of grass and weed competition, but tending operations such as climber cutting are necessary during the first two years to prevent bending of shoots. Generally, three weedings may be carried out in the first year during June-July, September-October and January-February. Soil working around the plants and mulching to a radius of 0.15 m should be done for all plants but particularly for the weaker ones. This may be done in February and March. During the second year, two weedings may be done. During the third, fourth and fifth year, complete knife weeding may be done. During weedings, the double leaders must be removed and damaged plants must be coppiced. Climber cutting may also be done, whenever required.

The recommended dose of fertilizer per tree is 50 gm of NPK in the first year, 100 gm in the second year and 150 gm in the third year. Apply manure or compost at a dose of 10 kg per planting hole before planting the tree. On acidic soils, soils with a low pH or soils with limited calcium (Ca), the area around the trees should be treated with lime (dolomite) to raise the pH. The recommended dose of dolomite is 150–250 gm per planting hole, applied at the same time as the manure or compost.

Unnecessary branches or twigs are pruned to obtain a clear bole and promote the tree's growth. The prunings can be used as fuelwood or sold for increased income by smallholder farmers. Prunings can also reduce the damage by forest fires because the separation of the tree crowns slows the spread of fire.

Thinning helps maximize tree growth, prevent the spread of disease and distribute trees more evenly. The trees harvested during thinning can be sold to raise income. Any harvested trees with diameters greater than 10 cm can be used for construction timber while the smaller ones are suitable for firewood. Teak planted at 2.5

m x 2.5 m can be first thinned at age 5-7 years, when the trees are about 7-10 m tall. In the first thinning, alternate trees are removed; subsequent thinnings are carried out at about 5-year intervals in the initial plantation years, and thereafter intervals are extended to 10 years as the plantation matures.

The next thinning is fixed at 15 years. In the subsequent thinnings at 20, 30 and 40 years the aim is to reduce competition and provide uniform gaps. During this operation only the required number of trees of very good quality should be retained. However, heavy openings in the canopy should be avoided. Where there is miscellaneous growth, preference should be given to teak. In places where stocking is poor miscellaneous species of comparatively good economic value should be retained (Chaturvedi and Khanna, 1994)

Plant Protection

White grubs feed on roots in the nursery. 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 purea)* 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. Avoid 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.

Suitable Agroforestry Systems

Teak is one of the favoured silvicultural species by the farmers. It is planted in different models, combinations as well as in different spacings. IFGTB (Institute of Forest Genetics and Tree

Breeding) has developed agroforestry models like agri-silvicultural (teak+casuarinas with agricultural crops such as maize, cotton, turmeric, tomato and chilly), agri-silvi-horticulture (teak+coconut with agricultural crops such as plantain, turmeric, vegetables, maize and cotton) and silvi-horticulture model (teak-guava, annona). Under irrigated lands, silvi-pasture model was developed with teak and casuarina as the tree component and napier and guinea as pasture components.

Teak+soybean agroforestry system

Yield and Utilization

The average productivity of teak in teak plantations in Nilambur, Kerala was 2.85 cu m/ha/year in 53 years rotation period. Recent studies conducted on teak growing in farmlands with irrigation, fertilizer application and management revealed the possibility of reducing the rotation period to 25 years and also achieve increased productivity. The trees in farmlands grow faster and produce more biomass than those in plantations in the forest areas. The quality of teak timber in farmland at 12 years was found to be similar to that

of 20 years in forest land. At best a tree may produce a maximum of 0.60 cu m of timber in 20 years under best conditions of intensive management and there could be a maximum of 100 trees per acre (KFRI, 1979)

***Tectona grandis* plantation**

Teak wood is globally renowned for its strength, durability, dimensional stability, working quality and non-corrosive property when in contact with metal. The durability is attributed to the deposition of polyphenols in its heartwood. On account of these outstanding properties, teak is sometimes hailed as the King of timbers. It is mainly used in furniture, cabinet making, various grades of plywood, panelling, construction, poles, piles, ship building and other purposes. Increasingly large quantities of Teak are used by the plywood industry for high grade commercial and tea-chest categories of plywood. Lops and tops and other rejects serve as fuelwood. The seeds contain oil to the extent of 44.5% and the oil is used in soap manufacture. Teak leaves are often used as platters.

References

Chaturvedi, A.N. and Khanna, L.S. 1994. Forest Mensuration (2nd ed.). International Book Distributors, Dehradun,, India

KFRI. 1979. Yields from teak plantations in Kerala. Kerala Forest Research Institute, Peechi.

Tiwari, D.N. 1992. A monograph on teak (*Tectona grandis*) Linn.f. International Book Distributors, Dehradun, India.

Chapter 25

Terminalia arjuna (Roxb) Wight & Arn

Family: Combretaceae
Common name: Arjun
Trade name: Arjun
Origin: India

Botanical Characters

Terminalia arjuna is a large, evergreen tree (20-25 m tall) with spreading crown and drooping branches. Stems rarely long or straight, generally always buttressed. Its bark is thick, smooth, exfoliating in large irregular sheets. The leaves are simple, sub-opposite to each other and are oblong or elliptic-oblong in shape. The flowers are stalkless and found in clusters or in axillary spikes. The fruits (drupe) are ovoid oblong, 5-7 hard angles or wings making it convenient for disposal by wind.

Trees of *Terminalia arjuna*

Distribution

T. arjuna is native to the Indian sub-continent and is distributed throughout semi-arid, sub-humid and humid tropical South Asia from Pakistan to Malaysia. It occurs in valleys and plains

up to 1200 m elevation. In India the tree species is commonly found in Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh and Orissa. It is also grown in Maharashtra, West Bengal, Andhra Pradesh and Uttar Pradesh. It is a characteristic plant of dry tropical riverain forest and riparian fringe forest (Champion and Seth, 1968). It is a preponderant species of the Gir forest (Santapau and Raizada, 1954). It grows well along banks of streams, rivers, ravines, dry water courses, reaching very large sizes on fertile alluvial loam.

Silvicultural Requirements

The plant naturally occurs in sub-tropical and tropical moist regions of the country, where the mean annual rainfall is 750–1900 mm and mean annul temperature ranges from 20 to 30 °C. The plant also survives in open sunny and low-rainfall areas. Arjun tree is a moderate shade-bearer, but does not tolerate dense overhead shade. Seedlings are sensitive to drought and frost, but grow well if moisture is available. It produces root suckers. Coppicing ability of the tree is satisfactory and it pollards well. The tree prefers neutral (pH 6.5 - 7.0) soils, alluvial loamy or black cotton soils, which are loose, moist, fertile, and have good drainage and water holding capacity. Cool, moist locations along streams, ravines or dry water courses are the ideal places for its good growth (Kadambi, 1954). It can also grow on saline, sodic and waterlogged sites.

Phenology

T. arjuna is usually an evergreen tree with new leaves appearing in the hot season before leaf fall. Trees may sometimes be leafless for a very short period before flowering. Fruit bearing begins 6-7 years after planting. Flowering occurs during April-July or May in Central India and the fruits ripen the following February-May (Troup, 1921), nearly a year after the appearance of the flowers. Generally, every third year is a good seed year (Ghosh, 1977) .

Propagation Technology

T. arjuna can be propagated through seeds, stumps and tissue culture.

Through Seeds

Collect the ripe fruits from trees or from the ground underneath the tree in April–May. Dry them in shade for a month and remove the ribs to extract the seeds by rubbing with hands or using a mechanical method. About 775-800 seeds make one kilogram. Seeds are viable for one year when stored dry in gunny bags, but germination is reduced to 10–20%. Soaking of seeds in cold water for 48 hours before sowing improves the germination percent. February-March is the right time for sowing. The seeds can be sown directly in polybags or in well prepared nursery beds. Generally, two seeds are sown in every polybag at a depth of 2.5 cm. In nursery beds, seeds are sown in rows 30 cm apart, with about 5 cm spacing between seeds. Irrigate immediately after sowing. Seeds start to germinate in seven days and continue to germinate up to 60 days. The germination rate of pre-treated seeds is up to 90%, while that of untreated seeds 50–60%. Maintain the seedlings in the nursery for 3–4 month and transplant them preferably in July, when they have grow up to 45 cm in height (about one year old).

Vegetative Propagation

Normally, 15-month old seedlings are used for preparing stumps. A collar diameter of about 1.2–2.5 cm is considered optimum for planting stumps. Plant them first in polybags in the nursery and maintain them for 3-4 months.

Vegetative propagation by air layers has been tried and 30 days old rooted layers show better survival after transplantation. The seedlings suffer from drought and frost (Gupta, 1994). The tree can also be propagated through tissue culture, but it is a costly technique and generally not recommended.

Cultural Operations

Planting

Preparatory tillage is done in the field, which should be levelled, and pits of size 45 cm x 45 cm x 45 cm are dug at a spacing of 6 m x 6 m. About 10 kg FYM (farmyard manure) and NPK (nitrogen, phosphorus, and potassium) at 75:50:30 gm are added per pit and thoroughly mixed with soil as basal dose. About one year old

seedlings are transplanted during rainy season in the pits. For tasar production, Arjuna is planted at 2 m x 3 m or 3 m x 3 m with square or rectangular planting. In agroforestry plantation for timber and medicinal purposes, trees are planted at the spacing of 4 m x 5 m or 6 m x 6 m.

Tending Operations

Weeding is a prerequisite for any plantation for its establishment and better growth in field conditions. It is recommended that at least one manual weeding be carried out during the first year of plantation. Intercropping with annual crops and their proper management helps in checking the weed growth.

Pruning is required to remove the weaker shoots when forking takes place. Dried branches are removed every year by using tree pruners to maintain proper sanitation in the plantation. Arjun tree is generally lopped for fodder. It is one of potential fodder species of low hills of Himachal Pradesh. The optimum lopping time to harvest nutrient-rich fodder for cattle is November-December.

Arjuna is also cultivated for rearing tasar silkworm in tribal areas of many states in India. In some areas, it is pollarded every year not only to produce young shoots and new foliage, but also to harvest cocoons at ease without climbing the tree. The height of a pollarded tree is 2.43-2.74 m.

Tree Protection

During rainy season, incidence of powdery mildew is observed in the early stages of growth, which is maximum during September. This can be controlled by spraying sulphur containing fungicide like Karathane (wet suphur) at 0.1 % . Some leaf-eating insects appear but it is advisable not to use synthetic pesticides particularly when bark harvesting is undertaken. Neem based pesticides may be used.

Infestation of Gall by the insect *Trioza fletcheri minor* in the tropical tasar silkworm food plants such as *T. arjuna* (Arjun) and *T. tomentosa* (Asan) is very common and causes significant damage to the foliage and negatively impacts the Tasar cocoon production. To control the damage by this insect an integrated package has been

developed, which consist of cultural (two times deep ploughing) and mechanical (collection and destruction of different developmental stages of insect such as eggs, grubs/larvae, pupae and adults of coleopteran and lepidopteran pests) practices, and soil application of neem cake and foliar application of Azadirachtin (6 ppm).

Suitable Agroforestry Systems

T. arjuna is an agroforestry species often intercropped with coconut and citrus. It is also an excellent shade tree, especially in coffee plantations. Arjuna planation can be raised for rearing tasar silkworms. Plantations established in India for rearing tasar silkworms have a spacing of 1 m x 2 m, and are managed by repeated pollarding. It also coppices strongly, if cut when smaller than 75 cm diameter at breast height. A dense spacing of up to 30,000 trees/ha gives an optimal biomass production. Arjuna is a common tree of Central India and farmers retain this tree on field bunds/boundaries. Rice+Arjun based agroforestry systems have also been reported in Madhya Pradesh. Integration of *T. arjuna* in various agroforestry systems, *viz*. agri-silvicultural system, silvi-pastoral system, multipurpose wood lot, and agri-horti-silvicultural system has been reported for reclamation of salt-affected soils (Behera et al. 2015).

Yield

The Arjuna tree starts flowering from the sixth year onwards. Bark is repeatedly scrapped in winter season. The bark is removed from well-grown trees, preferably from the 10^{th} year onwards, in spiral or vertical strips of not more than 5 cm width and 25 cm length. The bark is dried in well-ventilated shade and stored in boxes or polybags in dry and airy locations. About 500 kg dried bark can be obtained from 1 hectare of plantation every year from the 10^{th} year onwards.

The productivity of *T. arjuna* was investigated under varied plant spacing (10-, 20-, 30-, 40- and 50-thousand trees per hectare on a highly alkaline soil site (pH 8.6 to 10.5) in order to maximise biomass production and to assess optimum stocking density. The study showed that after 4 years an optimum biomass of 22.7 t/ha

was produced in the 30,000 trees/ha treatment. Densities higher than 30,000 trees/ha were found to be supra-optimal and resulted in over-crowding. The biomass produced in high density plantation of *T. arjuna* was found suitable for use in gasifiers. (Srivastava et al. 1999)

Utilization

The heartwood of Arjuna is hard, strong, moderately heavy, moderately durable, difficult to season and difficult to work. It is used locally for carts, agricultural implements, water troughs, boats, tool handles etc. It is also suitable for plywood industry and construction material. It is an excellent source of firewood and charcoal, with calorific values of 5030 kcals/kg (sapwood) and 5128 kcal/kg (heartwood). The bark (22-24%) and fruit (7-20%) are sources of tanning and dyeing. Arjuna leaves constitute one of the major feeds for the tropical tasar silkworm. The bark of the tree has been used for more than 3000 years primarily to treat cardiovascular diseases like angina, coronary artery disease, heart failure, hypercholesterolemia and hypertension.

Arjuna is one of the sacred trees of India. The leaves and flowers of the tree are offered to Lord Vishnu and Lord Ganesha on several religious occasions.

References

Behera, L., Nayak, M. R., Patel, D., Mehta, A., Sinha, S. K. and Gunaga, R. 2015. Agroforestry practices for physiological amelioration of salt affected soils. *Journal of Plant Science Physiology* 1(1):13-18.

Champion, H.G. and Seth, S.K. 1968. A Revised Survey of the Forest Types of India. Manager of Publications, Delhi.

Ghosh, R. C. 1977. Handbook of Afforestation Techniques. Controller of Publications, Delhi, 411 pp.

Gupta, R. K. 1994. Multipurpose Trees for Agroforestry and Wasteland Utilization. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, 557 pp.

Kadambi, K. 1954. *Terminalia arjuna* Bedd., its silviculture and management. *Indian Forester* 80 (11): 692-699.

Santapau, H. and Raizada, M.B. 1954. Contribution to the flora of Gir forest in Saurashtra. *Indian Forester* 80 (7): 379-389.

Srivastava, N., Goel, V. L. and Behl, H. 1999. Influence of planting density on growth and biomass productivity of *Terminalia arjuna* under sodic soil sites. *Biomass and Bioenergy* 17 (3):273- 278

Troup, R. S. 1921. The Silviculture of Indian Trees. Clarendon Press, Oxford, Vols. 1-3.