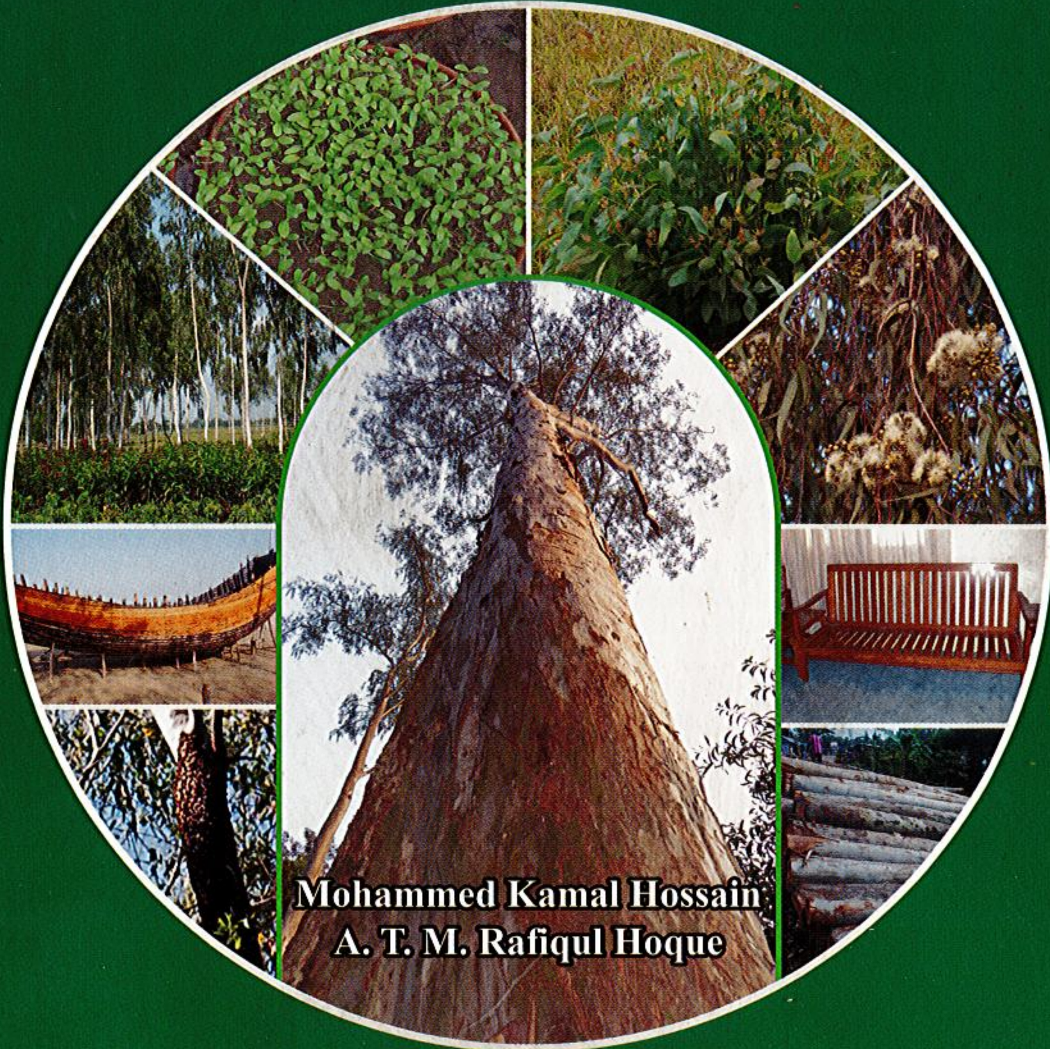
Eucalyptus Dilemma in Bangladesh



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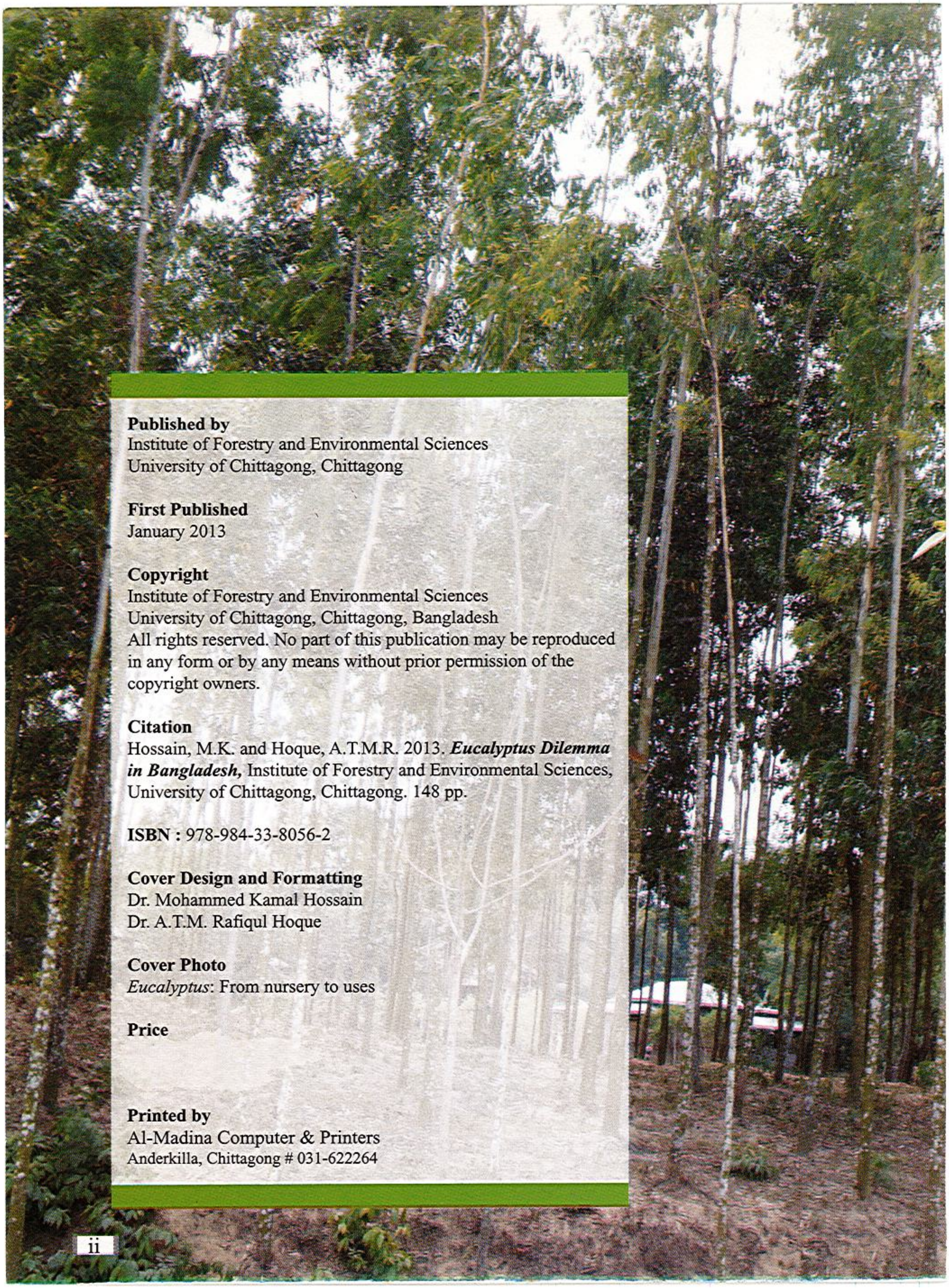

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Eucalyptus Dilemma in Bangladesh

Foreword

Bangladesh has a long history of plantation forests starting in 1871 with teak and plantations are expanding now more rapidly than ever before. Selection of species in plantation forests is a crucial issue because of their ability to fulfill the demand of all stakeholders and also the suitability of the species considering the environmental concerns. Eucalypts was introduced in Bangladesh as an avenue and ornamental trees in early 19th century but systematic selection and growth trial was established only in mid 1980's. *Eucalyptus camaldulensis*, *E. tereticornis* and *E. brassiana* were recommended for large scale plantation programs in Bangladesh, but controversies arose about the environmental impacts by planting the species in Bangladesh.

The book **"*Eucalyptus* Dilemma in Bangladesh"** is an outcome of research findings of Eucalypts in Bangladesh based on laboratory and field trials, compiling and generating secondary information available in different sources. The information provides a timely examination of the role of Eucalypts in environment and also providing the goods and services to the society. Though growing of Eucalypts in Bangladesh is still a controversial and crucial issue, individual and farmers are planting Eucalypts in their homesteads, marginal and wastelands and the plantations are increasing day by day. The book is able to address some of the common issues raised by planting Eucalypts in Bangladesh.

It is my pleasure to write this foreword in relation to the facts and figures of Eucalypts in Bangladesh. The initiative may address the long-left issue of environmental consequences of planting Eucalypts in Bangladesh. I congratulate the authors for such an initiative and believe that this will make a substantial contribution in the resolution of the debate on planting Eucalypts in Bangladesh.

Professor Dr. Mohammed Jashimuddin
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Foreword

Arannayk Foundation has been consistently promoting conservation of natural forests and indigenous tree species in Bangladesh. The demand for wood and fuelwood are increasing with increasing population. People living in and around forest areas had been collecting forest products both legally and illegally with consequent deforestation and degradation of forests.

To reduce their dependence on forests, Arannayk Foundation had been promoting alternative livelihoods among the forest dependent communities by proving them with revolving loan funds (RLF), as community grants, for that purpose. The RLF loans are generally interest free but the borrowers need to plant at least two saplings of indigenous endangered tree species at their own cost in their homestead or marginal lands for every Taka 1,000 but maximum of Tk 10,000. When we observed that such livelihood support could increase household income of the forest dependent communities and reduce their dependence on forests but except for fuelwood that they needed for cooking their foods. We asked them to select and plant some fast growing tree species in their homesteads to use as fuelwood. Most of our project participants wanted to plant *Eucalyptus,* Ipil Ipil (*Leucaena leucocephala*) and Akashmoni (*Acacia auriculiformis*) in their homestead along with *Albizia saman* (raintree). One of the reasons for choosing *Eucalyptus*, Ipil Ipil and Akashmoni is their fast growth and coppicing ability. We reminded them about criticism of exotic trees but they felt that planting one of few exotics in homestead would not affect the biodiversity. There are serious controversies about exotics in Bangladesh and elsewhere in the world. Most of the controversies emerged from the media which needed scientific validation.

This publication attempted to consolidate research findings of Bangladesh and compared those with findings of similar conditions elsewhere in the world. The publication contains general information about forests of Bangladesh and their biodiversity, history of plantations in the forests of Bangladesh which started with teak plantation in early 1870s followed by other species, introduction of exotic tree species including eucalypts and systematic research trials on them by Bangladesh Forest Research Institute (BFRI) for commercial plantation and criticisms over exotic species in general and eucalypts in perticular. The authors documented reactions of eucalypt planters through few case studies.

Natural forests provide better habitat for wildlife compared to plantation. However, to meet the increasing demand of timber and fuelwood there is need for plantation. Bangladesh is one of the pioneering countries in the world in coastal afforestation. Bangladesh Forest Department made a splendid job through demonstrating establishment of successful coastal afforestation which is a lesson for other countries of the world. The plantation along the coast is contributing in mitigating climate change effects particularly saving the life and properties of people living along the coasts from cyclone and tidal surges. Though the most widely planted species of

coastal afforestation, Keora (*Sonneratia apetala*) is having a stem borer problem, it is possible to find out resistant variety and have new plantation with better genotype evolved through research. Other than coastal areas, the main plantation species throughout the world, perticularly in tropical and sub-tropical countries is *Eucalyptus*. Large scale plantation exists in India, Brazil, China and other countries. The species has wide range of uses. It grows in extreme climatic condition and in poor sites. However, there are controversies about the impact of the species on environment and other crops.

Systematic research on *Eucalyptus* was started in Bangladesh during late '70s though the species was introduced in the country as an avenue and ornamental tree in early 19th century. Bangladesh Forest Research Institute tested different species and provenances of *Eucalyptus*, *Acacia auriculiformis*, *Acacia mangium* and Ipil Ipil from Australia. Through elimination trial, provenance trial, and growth trial under different ecosystems of Bangladesh, BFRI recommended only three species of *Eucalyptus* for large scale plantation namely *Eucalyptus camaldulensis*, *Eucalyptus tereticornis* and *Eucalyptus brassiana* during mid '80s of 20th Century. The initial growth of the species was extremely encouraging. For their fastest growth, people were encouraged to plant the species especially *Eucalyptus camaldulensis* and Akashmoni for commercial purposes in their crop lands and marginal lands. These species performed better in the northern Bangladesh than in other regions of the country and hence these species spreaded more in that region. However, there were criticisms about their allelopathic impacts on soil and other crops including depletion of ground water table. Scientists in Bangladesh and elsewhere studied the effect of *Eucalyptus* on all those aspects. This publication has compiled and consolidated the findings of the various studies on *Eucalyptus*.

The information provides a timely examination of the impact of Eucalypts on environment and its role in providing necessary goods and services to the society. It appears that planting the species as monoculture over larger areas definitely changes physical and chemical properties of soil but when they are planted sparsely in the homestead and elsewhere do not affect much.

The last chapter presented few case studies of planting *Eucalyptus,* which described how the species benefited the families and what problems they observed.

The information will help others to decide about planting the *Eucalyptus* in particular and exotic in general. Thanks to the authors for their hard work in collating and compiling the information about the exotic species and their impacts on soil and climate.

Farid Uddin Ahmed
Executive Director
Arannayk Foundation

Preface

The population of Bangladesh is growing rapidly. The natural forest areas and native forest tree species are decreasing in an alarming rate. The gap between the demand and supply of forest products are widening day by day. Instead of traditional forest management, plantation forestry and agroforestry practices have become an increasingly important source of timber, firewood, pole and posts. Bangladesh has a long history of plantation forests starting from 1871 with teak bringing the seeds from Myanmar (Burma). Till to date teak is the dominant species in plantation forests but the species is limited in the plantation forests of Forest Department and the Jothlands of CHT. To address the huge demand of the forest produces, initiatives were taken in the late seventies to find out the fast growing species of both exotic and indigenous ones. *Acacia* and *Eucalyptus* were the most successful species for providing poles, posts and firewood within a short period. Species elimination trial, provenance trial and growth trial of *Eucalyptus* species proved successful in wider range research centers of Bangladesh Forest Research Institute (BFRI) and elsewhere in the country. However, the question of large scale mono-plantation of *Eucalyptus* became a concern among the researchers, policy makers, growers and environmentalists. Media played a significant role about negative impacts of *Eucalyptus* in Bangladesh and the neighboring countries. Bangladesh Government took a decision of banning the species from further plantation programs without having strong scientific findings of the species, even the species was recommended only after a series of trials. In some cases, the established eucalypt plantations were also felled. But, the farmers and individual growers are still planting the species; even eucalypt is becoming a dominant species in some upazila and districts. The species is significantly contributing in the wood products of the country and people prefer the species for its faster growth rather than environmental hazards. However, the species is highly productive and well adapted to dry, infertile degraded sites.

The book is the outcome of a series of research experiments of both in the Bangladesh Forest Research Institute, Institute of Forestry and Environmental Sciences of Chittagong University along with the relevant secondary information. We tried to incorporate the real situation of both the positive and negative impacts of growing Eucalypts in Bangladesh. Native tree species must be given priority in plantations programs but considering the immediate return, Eucalypt is the preferred species in plantations forests. Scientific management of plantations, improved silvicultural techniques, quality planting materials, species-site matching and mixed plantations of the fast growing species may reduce the gap of huge demand of forest produces of the country.

Mohammed Kamal Hossain
A.T.M. Rafiqul Hoque

Chapter 1

Forests of Bangladesh

1.1 Forest Area

The total area of Bangladesh is 14.757 million hectares (BBS 2005). Information on forest statistics in Bangladesh vary considerably from one source to other. Nevertheless, there is a general demand of reliable information in this regard. In Bangladesh, of the total area cultivated land makes up 56% of the geographic surface, forest lands account for almost 10.0% (14,43,000 ha), almost 20% as villages, 14% as inland water and less than 1% as build up areas. Of the total forest area, 84% has been classified as natural forest and 16% as plantation forest (Altrell *et al.* 2007) and the forest areas according to national land use classes are shown in Table 1.1.

Table 1.1 Total forest areas of Bangladesh by National Land Use Classes (Altrell *et al.* 2007)

Forest Areas		National Land Use Classes and area		%
14,43,000 ha	Natural Forest 12,05,000 ha	Hill Forest	5,51,000 ha	38
		Sal Forest	34,000 ha	2.3
		Mangrove Forest (salt water)	4,36,000 ha	30.2
		Bamboo or mixed Bamboo/ broadleaved forest	1,84,000 ha	12.7
	Forest plantations 2,38,000 ha	Long rotation forest plantation	1,31,000 ha	9.1
		Short/medium rotation forest plantation	54,000 ha	3.8
		Mangrove plantation (coastal)	45,000 ha	3.1
		Rubber plantation	8,000 ha	0.5

Much of the Government forest lands do not have satisfactory tree cover (World Bank 1997, Chowdhury 1999, Ahmed 2003) and only 0.84 million ha (about 5.8%) of the state forest land has good forest cover (FSP 2004).

1.2 Forest Distribution and Composition

1.2.1 Hill Forests: The hill forests of Bangladesh are situated in the eastern border of the country in relatively high altitude hills found in Chittagong Hill Tracts, Chittagong, Cox's Bazar and Sylhet. Hill forests of Bangladesh are ecologically divided into two classes: (a) tropical wet evergreen forests, and (b) tropical semi-evergreen forests (Das 1990).

The Tropical Wet Evergreen Forests: The tropical wet evergreen forests are an important class of forests in Bangladesh in terms of biodiversity, forest assets and environmental concerns. These are magnificent dense evergreen forests rich in floral and faunal composition. The trees in the top canopy reach a height of 45-60 m (**Fig. 1**). A few semi-evergreen or deciduous species may occur but they do not really change the evergreen nature of the forests. The forests' floral diversity is rich with epiphytes, orchids, and woody and

Figure 1. Sangu Reserve- a rich harbor of forest biodiversity

non-woody climbers, ferns, mosses, aroids, and palms, particularly in northern shady moist places. Herbs and grasses are abundant and the undergrowth is a tangle mass of shrubs, bamboo and cane. These forests occur usually in hills and moist shady areas in Chittagong Hill Tracts (Khagrachari, Rangamati and Bandarban), Sylhet, Habigonj, Moulavibazar, Cox's Bazar and Chittagong (Das 1990). Major dominant tree species are boilam (*Anisoptera scaphula*), chapalish (*Artocarpus chama*), garjan (*Dipterocarpus turbinatus, D. alatus, D. costatus*), telsur (*Hopea odorata*), champa (*Michelia champaca*), narikeli (*Pterygota alata*), civit (*Swintonia floribunda*) etc. (**Fig. 2**).

Figure 2. Dipterocarp dominant natural forests in Silkhali Range, Cox's Bazar

The Tropical Semi-Evergreen Forests: This type of forests occurs in Cox's Bazar, Chittagong (**Fig. 3**), Chittagong Hill Tracts (**Fig. 4**) and Sylhet, in more exposed dry locations. The top canopy species of the tropical semi-evergreen forests reach a height of 25-57 m. In this forest, the evergreen species predominate, but also there are many deciduous species. As a result, during winter the forest gives a semi-evergreen (green cover with some distinct brown leafless tree crowns) view to distinguish it from the pure evergreen forests. Many of the species of evergreen forests also occur in this type of forests.

Figure 3. Tankawati natural forests at Padua, Chittagong (South) Forest Division

Figure 4. Natural forests at Sitapahar, Kaptai, Rangamati

1.2.2 Tropical Moist Deciduous Forests: The tropical moist deciduous forests are popularly known as Sal forests. These forests occur in Dhaka, Gazipur, Tangail, Mymensingh, Sherpur, Jamalpur, Netrokona, Dinajpur, Rajshahi, Panchagar, Rangpur, Noagaon, and a small patch in Comilla (Chowdhury 1994). In these forests, the predominant species is Sal (*Shorea robusta*). The trees are 10-25 m in height, and mostly deciduous (**Figs. 5 and 6**). Associate species are palas (*Butea monosperma*), haldu (*Adina cordifolia*), sidha jarul (*Lagerstroemia parviflora*), kumbi or gadila (*Careya arborea*), hargaza or ajuli (*Dillenia pentagyna*), bhela or beola (*Semecarpus anacardium*), koroi (*Albizia* spp.), gandhi gazari (*Miliusa velutina*), menda (*Litsea monopetala*), kusum (*Schleichera oleosa*), chapalish (*Artocarpus chama*), udal (*Sterculia* spp.), depha jam (*Cleistocalyx operculatus*), bahera (*Terminalia bellirica*), kurchi (*Holarrhena antidysenterica*), horitaki (*Terminalia chebula*), kapila (*Garuga pinnata*), raina or pitraj (*Aphanamixis polystachya*), sheora (*Streblus asper*), sonalu (*Cassia fistula*), assar (*Microcos paniculata*), amloki (*Phyllanthus emblica*) etc.

Figure 5. Remnant natural sal forests in Birgonj, Dinajpur

1.2.3 Mangrove Forests: Mangrove forests, both natural and plantations are very important forest resources in Bangladesh. These are also called littoral swamp forests. These are mainly evergreen forests of varying density and height, always associated with wet soils. The mangrove forests are well developed in the Sundarbans on the Ganges- Brahmaputra Delta (Siddiqi 2001).

Figure 6. The last natural patch of sal forests in Madhpur, Tangail

The Sundarbans mangrove area is now a World Heritage Site. Sundri (*Heritera fomes*) is the dominant tree species after which the forest is called the Sundarbans. The total area of the Bangladesh Sundarbans is 6,017 km^2, which is the single largest (considering whole Sundarbans area including Indian part) natural mangrove tract in the world. It is about 4.2

percent of the total land area of Bangladesh and about 44 percent of the forest land in the country (FMP 1993). Other associate species are *Excoecaria agallocha*, *Avicennia officinalis, Rhizophora mucronata, Bruguiera sexangula* and *Ceriops decandra*. Many others also constitute the tidal or mangrove vegetations (**Fig. 7**).

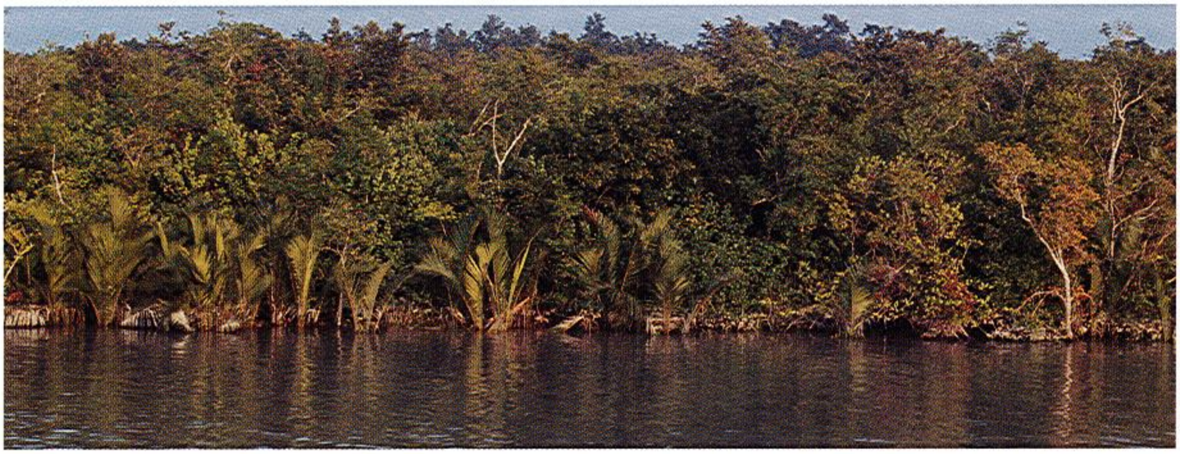


Figure 7. The world famous Sundarbans mangrove forests

The Sundarbans Reserve Forest has been managed as a productive forest since 1879. The Sundarbans is a very vital natural forest providing a large number of products, such as timber, fuelwood, fish, thatching materials, honey, bee wax and shells (Siddiqi 2001). In addition, it supports a very rich and diverse flora and fauna (Das and Siddiqi 1985, Siddiqi 2001). It is the largest remaining habitat for the Royal Bengal Tiger. Some 6,00,000 people are directly dependent on these resources for their livelihood. The mangrove forest acts as a natural barrier to cyclones and tidal bores, and protects the densely populated agricultural areas in the mainland. The Sundarbans also act as the world's largest mangrove carbon sink. These are also an important spawning ground for fishes and harboring a very rich biodiversity. Unfortunately, the other mangrove forest known as the Chakaria Sundarbans is already degraded for salt, shrimp culture and habitations (**Fig. 8**).

Figure 8. The remnant patches of Chakoria Sundarbans

However, the coastal plantations of keora and jhau are very promising (Hossain 2010) and provide shelter, wood and amenity for the coastal people (**Figs. 9 and 10**).

Figure 9. Keora plantations in the coastal areas

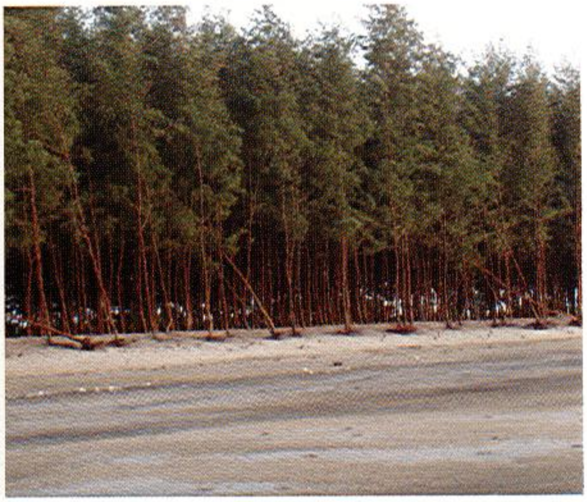


Figure 10. Jhau plantations in the sandy beaches of Kutubdia island

1.2.4 Homestead Forests: Planting trees near homesteads is a traditional land use system in Bangladesh. Homestead forests develop as small groves scattered around homesteads through ecological and anthropogenic selections (Alam and Masum 2005). Multi-layered vertical stratification, species diversity, and diversity of economic plants rather than number of individual species are characteristic features of Bangladesh homestead forests. The homestead flora of Bangladesh ranges from seasonal annual herbs to woody perennials including indigenous and exotic species of multiple uses (Khan and Alam 1996). The homestead vegetation can broadly be stratified into three strata. Trees are the dominant and common feature of the homestead flora (**Figs. 11 and 12**).

Figure 11. Paddy fields end with rich homestead forests

Figure 12. Eucalypts are becoming dominant in homesteads of some areas

Common trees of the upper stratum of a typical homestead forest are *Albizia procera, Aphanamixis polystachya, Artocapus heterophyllus, Artocarpus lacucha, Polyalthia longifolia, Alstonia scholaris, Azadirachta indica, Dillenia indica, Mangifera indica, Acacia auriculiformis, Elaeocarpus floribundus, Bombax ceiba, Syzygium cumini, Albizia saman, Swietenia macrophylla, Tamarindus indica, Toona ciliata, Acacia nilotica, Lagerstroemia speciosa, Ficus benghalensis, F. religiosa, F. racemosa, Anthocephalus chinensis, Eucalyptus camaldulensis, Areca catechu, Borassus flabellifer, Cocos nucifera, Gmelina arborea, Erythrina orientalis, Lannea coromandelica* and *Litsea monopetala* (Khan and Alam 1996).

The mid stratum is dominated by medium-size to small trees, and bamboos. Among them common species are *Holarrhena pubescence, Microcos paniculata, Citrus grandis, Ehretia serratam, Mallotus philippensis, Cassia fistula, Pithecellobium dulce* and *Phoenix sylvestris*. Besides, *Bambusa balcooa, B. cacharensis, B. comillensis, B. nutans, B. salarkanii, B. tulda* and *B. vulgaris* are common bamboo species. Common shrubs include *Adhatoda zeylanica, Cajanus cajan, Glycosmis arborea, Citrus* spp. *Duranta repens, Pithecellobium dulce, Euphorbia antiquorum, Sesbania* spp., *Lawsonia alba, Calotropis procera, Murraya* spp., *Grewia* spp. Many of them are of medicinal value, and some of them are used as hedge plants. *Barringtonia acutangula, Crataeva magna, Erythrina fusca, Pongamia pinnata, Trewia nudifolra are* common trees that grow along water edges in low-lying areas (Alam *et al.* 1991). *Calamus tenuis* is a common rattan of the village forests.

1.3 Present Forest Management

Forest management today is almost totally different from the past in respect of its objectives and philosophy. Present-day forest management objectives are not only to produce timber but also to provide clean air, clean water, and a healthy habitat for wildlife and to act as a major harbor of biodiversity and nature based tourism. The present objective is to involve people in the management of forest resources and create an environment, so that people can feel that they have also a share on trees growing on forestland as well as to improve the living standard of people residing in the vicinity of the forest. Present-day forest management is primarily guided by the Forestry Master Plan (FMP) completed in 1993. But, the degradation of forest in Bangladesh is a common problem and the problem is getting worsened in a wide range of forest areas.

1.4 Degradation of Forests of Bangladesh

There are many forces responsible for forest degradation, collectively and individually. The trends of these forces are very complex. The major causes of forest degradation in Bangladesh are agricultural expansion, over-extraction of wood and non-wood resources, infrastructure development, population growth, deforestation, settlement, urbanization and inappropriate management practices (Hossain 1998, Salam *et al.* 1999, Hasan and Alam 2006). The state of forest degradation in Bangladesh and their major causes are highlighted in the following sections.

1.4.1 Deforestation

The loss of forest cover in Bangladesh still remains at an estimated figure and their exact size and location are not conclusively determined, except for periodic visual observations (FMP 1993). These estimates indicate that damage affects one eighth of the country's land area. The different estimates of deforestation reported in various sources are not consistent (Khan *et al.* 2004). In the absence of survey and demarcation of areas classified as forests, it is not possible to improve the information base. However, estimation is that about half of the land area controlled by the Forest Department lacks tree covers (**Figs. 13 and 14**).

Figure 13. Massive deforestation in remote natural forests of Mandirachara, Bagaichari

Figure 14. Deforestation in Teknaf WS area

Deforestation results mainly from land clearing for agriculture, principally shifting cultivation. Other causes include land use changes, encroachments, grazing, fire, uncontrolled and unscientific commercial logging, and clear felling for plantations, illegal felling and fuel wood collection, erection of brick fields and expansion of tobacco cultivation in the vicinity of forests in some hill districts. The direct causes are the symptoms or effects of a wide malaise-poverty, landlessness, economic under-development, implementation of regulations, lack of land use planning, uncertainities in land tenure system and socio-political instability. The annual deforestation rate is estimated to be 3.3% (Khan *et al.* 2004). Consequently, per capita forest land is declining. The impacts and manifestations of such alarming rate of deforestation are multifaceted.

1.4.2 Shifting (Jhum) Cultivation

Shifting cultivation goes with primitive economies and isolated cultural communities in the hilly areas of Bangladesh. Shifting cultivation is characterized by a rotation of fields rather than by crops, accompanied by slash and burning (Kerkhoff and Sharma 2006). In a situation of little or no population or market pressure, shifting cultivation is environmentally acceptable. There were stable cases of integrated land use, and good agroforestry. However, with a developing market economy and the inevitable population pressure on land, the once elegant system of shifting cultivation collapsed into degradation and retrogression, influenced by factors both internal and external to the system. Control or regulation of jhuming is not effective resulting vast tracts in the hill regions denuded. About 60,000 families are engaged in shifting cultivation covering an area of about 85,000 hectares of the hill forest area of Bangladesh (**Figs. 15 and 16**).

Figure 15. Jhum - a traditional land use system in Bandarban hill districts

Figure 16. Jhum in Rangamati hill districts

Clearing of natural vegetation for cultivation of pineapple, ginger and turmeric along the slopes has a negative effect, which increases soil erosion in the hilly areas. After 5-7 years of cultivation by this method, these lands totally degrade to an almost irreversible state. Clearing of forestland for settlements and unscientific land management for agricultural use accelerate erosion of the topsoil through extensive surface runoff caused by heavy monsoon rain. In addition, the infertile heavily compacted soil is exposed to the surface as a result of topsoil removal (Farid *et al.* 1992).

1.4.3 Encroachment

Encroachment is a serious problem both in the plain land sal forests and in the hill forests; however, information available about encroachment is scarce (FMP 1993). Encroached lands lack legal surveys and the exact area involved is unknown. Current data are the visual estimates of the Forest Department field staffs. The encroachment problem in the forest areas of Chittagong, Chittagong Hill Tracts and Cox's Bazar is political and involves both the Rohingya and cyclone refugees (Hossain and Rahman 1994) (**Figs. 17 and 18**).

Figure 17. Encroachment is a burning issue in hill forest areas

Figure 18. Rehabilitation of Rohingya refugees in Kutupalong, Ukhiya also destroy forests

Figure 19. Encroachment is also severe in sal forest areas in north Bengal

Figure 20. Accreted coastal lands are used for habitation and agricultural crops

Figure 21. Chakoria Sundarbans converted to salt bed

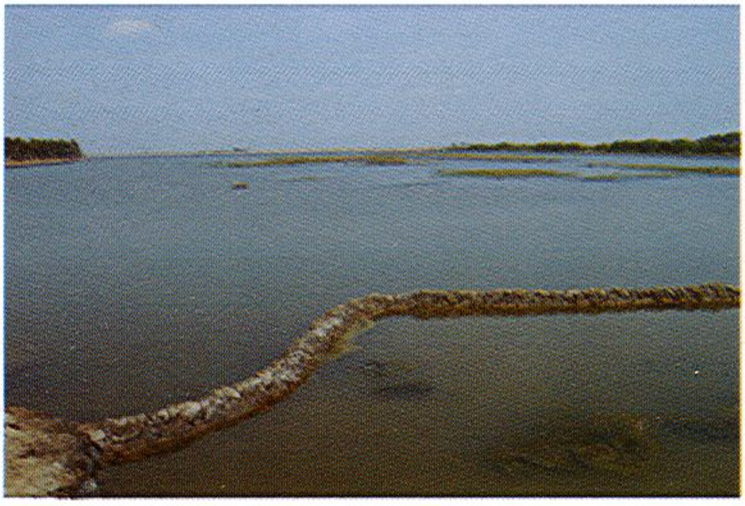


Figure 22. Chakoria Sundarbans converted to shrimp farm

Encroached sal forests in central and northern Bangladesh result from tenural uncertainties (**Fig. 19**). Organized encroachments carried out by politically powerful local groups also exist **Fig. 20**). The Forest Department is unable to control these encroachments. Lack of coordination between the Land Department, Administration and the Forest Department in land transfers and records add to the problem. Some 77,000 ha of forest land involving 12,200 families are estimated to be encroached in this way (FMP 1993). The total Chakaria Sundarbans are encroached for salt and shrimp farmings (**Figs. 21 and 22**).

1.4.4 Land Transfers to Other Uses

Land transfers have taken place where forested land get diverted for human settlement, development of industry, fishery, transport and communications, irrigation, energy and power, mining, tourism, educational institutions and defense. The extent of such transfers of forest lands was about 61,000 ha.

1.4.5 Population Pressure

The population density of Bangladesh is 941 per km^2 (Anon 2006), which is one of the highest in the world. In 1947, the density was only 306 per km^2 and the demand for forest produces as well as land for settlement was very little. In 1971, the density increased to 510 per km^2 and the demand for forest produces as well as land for settlement increased by 67 percent. At present, the density is 941 per km^2. In comparison to 1947 baseline, the demand for forest produces as well as land for settlement increased by 189 percent. Thus, the population explosion is the single most important factor for destruction of forests. Unequal distribution of resources among the population is also contributing to the destruction of forests. Firewood and leaf-litters are being continuously removed from the forests to mitigate the demand of the huge populations (**Figs. 23 and 24**).

Figure 23. Firewood collection is a regular practice in forests areas

Figure 24. Not only firewood, but leaf-litters are also removed from the forest floor

1.4.6 Settlement and Urbanization

Population growth is estimated at 1.43 percent per annum. Thus, additional land is needed to feed, homes to live, schools to educate, and hospitals to provide health care services. To meet all these demands, the only available land in this land-hungry country is the forestland. Conflict also arises from the settlers with rehabilitation in CHT in 1980 (Roy 1997). On the other hand, industrialization is also emerging at a rapid pace engulfing the scarce land. Climate change refugees are fueling these problems gradually. The situation in hill forest areas of Cox's Bazar, Sitakunda- Mirersoroi and CHT is the example of such migrations (**Figs. 25 and 26**).

Figure 25. Settlers gradually encroaching the forest lands

Figure 26. Habitation and infrastructure development in forest areas

1.4.7 Wrong Management Practices

In order to meet the increasing demand of forest produces, the Forest Department adopted a forest management practice called clear felling followed by artificial regeneration systems in the hill forest areas. Later on this proved to be very detrimental to sustainable hill forest management. Following this system, the forest was cleared by slash and burning of all vegetation, and replanted with only one or two commercially important species (e.g. mono-plantation of teak) (**Figs. 27 and 28**). As a consequence, the rich biodiversity of the hill forest ecosystem was destroyed as well as its soils exposed to erosion through torrential rains during the monsoon. The opening up of forests also tempted some people to encroach the forest land.

Figure 27. Clear-felling followed by artificial regeneration is a common practice in plantation forestry

Figure 28. Teak was first introduced in plantation forests

1.4.8 Brick Fields

Brick fields in the vicinity of forests have been identified as one of the notorious causes of deforestation (**Fig. 29**). Brick field owners who are the elites and patrons within existing power structures, have good liaison with political and government officials. They deploy local musclemen who instigate landless, job hungry people to illicit harvesting of forest resources. Brick fields in the vicinity of forests have caused not only deforestation, but it has also caused environmental degradation of the biological production systems. Farmers of many areas reported that their fruit production in the areas had declined because of smoke originating from the brick fields. Moreover, the energy used for firing bricks comes from woody biomass of the forests.

Figure 29. Brick field in the vicinity of forest destroys natural forests

Figure 30. Tobacco cultivation is responsible for forest destruction and food security

Figure 31. Tobacco cultivation in natural forest areas of hill districts

1.4.9 Saw Mills

Saw mills in the district and upazila headquarters and, also along the borders in adjacent districts possessing forests have created a demand for timber processing. This demand has caused an increase in harvesting forest resources both from public and private forests.

1.4.10 Tobacco Cultivation

Extension of tobacco cultivation in Lama, Ali Kadam and Naikhongchhari upazila of Bandarban district, and recently in Khagrachari and Rangamati has also contributed towards deforestation in two ways: through bringing fringe forest lands under tobacco cultivation and, supplying fuel wood for tobacco curing from adjacent forests (**Figs. 30 and 31**). In Bangladesh, the tobacco growing area has decreased from 32,822 ha in 1997-98 to 29,377 ha in 2007-08, but cultivation is increasing day by day in certain parts of the country, e.g. in CHT (Motaleb and Irfanullah 2011).

However, some tobacco companies are contributing in plantation programs to compcnsate the fuelwood uses, but this is not sufficient for the barns and curing of all the tobacco leaves growing in the hilly areas.

1.4.11 Patronage of Timber Traders

Patronage of traders in illicit harvesting of timbers is also a contributing factor towards deforestation. Generally, during the lean period of food production in April to August, there is little scope to sale labours. Many timber merchants take this opportunity and engage agents who instigate and encourage the people for illicit harvesting of bamboo, fuelwood and timbers (**Fig. 32**).

Figure 32. Illicit harvesting by timber traders also destroys the forests and forest resources

1.4.12 Policy Conflict

Conflict over policies is one of the important and major causes of deforestation in the CHT. Clear felling followed by monoculture of teak, introduction of recent exotics by the Forest Department; allotment of land for rubber plantation; upland settlement programs coupled with rubber plantations, loosely coordinated and integrated development programs have caused significant deforestation. These have also been an important cause of biodiversity loss. Lack of integrity among some government officials, political and community leaders have influenced policies and local level decision making processes which, ultimately added to the underlying causes of deforestation. Land tenure conflict in the CHT is added much to this problem.

Chapter 2

Plantation Forests in Bangladesh

2.1 What is Plantation?

Generally as a term, plantation is informal and not precisely defined. Literally plantation is a vast area of land where trees are grown with specific goal. Plantation is the act or practice of planting or setting in the land for growth. A plantation is defined as "A forest crop or stand raised artificially, either by sowing or planting" (Ford-Robertson 1971). Sometimes plantation means garden consisting of a small cultivated wood without undergrowth. Since the protective and environmental roles of plants were acknowledged by the global community, plantation was thought to be a large artificially established forest, farm or estate, where crops are grown for sale, often in distant markets rather than for local on-site consumption. However, recently the objectives and importance of plantation are getting high value considering the environmental and social values of crops. As a result, now they are not considered to be only a monospecific garden consisting of a small cultivated wood without undergrowth, rather this is considered to bring multipurpose outcomes including all intangible benefits provided by trees.

2.2 Plantation in the Tropics

Interest in plantations in the tropics is increasing rapidly (Evans 1992). The plantations have some advantages over natural forest from management and economic point of views, such as concentrated production, ability to choose species with desirable characteristics. Three genera, *Eucalyptus*, *Pinus* and *Tectona* account for 85% of all plantations in the tropics (Evans 1992). The major plantation species in the tropics with their occurrence are shown in Table 2.1.

Table 2.1 Major plantations species in the tropics

Pines	*Pinus patula, P. caribaea, P. elliottii, P. kesiya, P. markusii, P. oocarpa*	34%
Other Conifers:	*Araucaria cunninghamii, A. angustifolia*	3%
Eucalypts	*Eucalyptus grandis, E. camaldulensis, E. globulus, E. saligna, E. deglupta, E. tereticornis, E. robusta, E. citriodora and E. urophylla*	37%
Teak	*Tectona grandis*	14%
Other hardwoods	*Acacia mangium, Acacia auriculiformis, Gmelina arborea, Albizia* spp. etc	12%

2.3 Beginning of Plantation Forests in Bangladesh

The first attempt of raising forest plantation in Bangladesh in the then British colonial period was made in 1871 with teak in the Chittagong Hill Tracts (**Fig. 33**).

Since then, plantation forestry has become a part of the overall clear felling followed by artificial regeneration (in short plantation) management system of the hill forests (**Figs. 34, 35** and **36**). Today of the total forest area, 84% has been classified as natural forest and 16% as plantation forest. Later from 1921, some important hardwood species like *Swietenia macrophylla*, *Lagerstroemia speciosa*, *Cedrella toona*, *Artocarpus chama*, *Xylia kerii*, *Syzygium grande* were introduced in the plantation program along with Tectona grandis (Chaudhury 1982, Das 1982, Hossain 1998). In the 1950's and 1960's, sal (*Shorea robusta*) plantations were established over substantial areas in Chittagong and Chittagong Hill Tracts (Bhuiyan 1979). In this way, the natural multistoried diversified forests of Bangladesh were under the process of conversion from natural to artificial through the removal of existing growing stock and planting with more valuable species and also with lightwood and firewood species (Hoque 1977).

Figure 33. Teak plantation in Kaptai, Chittagong Hill Tract

Figure 34. Garjan plantation in Bamu natural forests, Lama, Bandarbon

Till 1997 about 2,10,162 ha plantations were raised in the hill forests (Hossain 1998). Now, this plantation is providing timber, pole, fuelwood and pulpwood and helping to conserve biodiversity and environment (Table 2.3).

Table 2.3 Forest land (ha) under different forest types in Bangladesh

Forest type	Natural forest	Plantation forest	Total forest	% of the total area of the country
Hill Forest	11,06,560	2,10,162	13,16,722	9.1
Littoral /Coastal	6,16,589	1,34,700	7,51,289	5.2
Sal Forest	87,213	36,013	1,23,226	0.9
Village Forest	------	2,70,000	2,70,000	1.8
Total	18,10,362 (1.81 m ha)	6,50,875 (0.65 m ha)	24,61,237 (2.46 m ha)	17.0

2.4 Introduction of exotics

In many situations exotics have proved to be faster growing than native species. Plant introduction or migration from one place to another, may be both natural and planted, and is a continuous process (Islam 1991). New plants coming to a place got new home to establish. After successful establishment they are then started to spread by different agencies, and thus become an exotics. Some exotics became so successful that they show more comfortable than their places of origin. Some of the exotic plants even became dominant vegetation in the new places. Bangladesh, like many other countries have a long history of plant introduction from the distant places and even the remote corners of the world (Islam 1991). Through the routes of air, land, maritime and inland water, many plants have been brought by settlers, invaders and traders. In this way of introduction many such plants became a part and parcel of Bangladesh flora (Hossain 2008). Hossain and Pasha (2004) reported 302 exotics in Bangladesh belonging to trees, shrubs, herbs and lianas, of which 94 tree species are known to be planted in trial or large scale plantation programs (Table 2.4).

Table 2.4 Exotic tree species so far tried in Bangladesh

Sl. No.	Scientific name	Local/ English name	Origin	Status of the species
1	*Acacia aulacocarpa*	Black wattle	Australia	Recently introduced and limited in trial plantations
2	*Acacia auriculiformis*	Akashmoni, Northern black wattle	Australia	Widely cultivated in forest plantation, roadside and homesteads
3	*Acacia catechu*	Khair, Catechu	Western India	Cultivated and wild for wood and tannin in northern area of the country
4	*Acacia cincinnata*	-	Australia	Recently introduced and limited in trial plantations

Sl. No.	Scientific name	Local/ English name	Origin	Status
5	*Acacia crassicarpa*	Northern Wattle	Australia	Recently introduced and limited to trial plantations
6	*Acacia holosericea*	Wah-roon	Australia	Recently introduced and limited to trial plantations
7	*Acacia mangium*	Mangium	Australia, Papua New Guinea	Widely planted in tea states, forest plantations and roadsides
8	*Acacia nilotica*	Babla, Gum arabica	Tropical Africa/ India	Wild and cultivated for wood and fuelwood
9	*Acacia polystachya*	----	Australia	Recently introduced and limited to trial plantations
10	*Acacia senegal*	Arabic acacia	West Africa	Introduced and limited to trial plantations
11	*Achras zapota*	Sofeda	South America	Well known cultivated fruit tree
12	*Acrocarpus fraxinifolius*	Pink cedar	South India	Occasionally grown as timber tree
13	*Adansonia digitata*	Baobab	Tropical Africa	Ornamental tree, rarely planted
14	*Adenanthera pavonina*	Raktakambal	China, Malaysia	Occasionally planted as timber tree
15	*Ailanthus excelsa*	Bassora, Madala	Peninsular India	Occasionally planted as timber tree
16	*Albizia richardiana*	Raj Koroi	Madagascar	Planted as avenue and timber tree
17	*Albizia saman*	Ful koroi, Rain tree	West Indies	Frequently planted as avenue and timber tree in homesteads
18	*Alstonia macrophylla*	Sri Lankan Chatian	Sri Lanka	Limited plantation in different Silviculture Research Stations of Forest Research Institute
19	*Anacardium occidentale*	Kaju badam, Cashew nut	South America	Limited cultivation for fruit and nut in CHTs and elsewhere
20	*Araucaria columnaris*	X-mass tree	South America & Pacific Island	Occasionally planted as ornamental tree
21	*Araucaria cunninghamii*	Hoop pine	Australia	Occasionally planted as ornamental tree
22	*Areca catechu*	Supari, Areca nut	Philippine/ Malaysia	Widely cultivated for nut particularly in homesteads
23	*Artocarpus heterophyllus*	Kanthal, Jack fruit	Western ghat of India	Widely cultivated for fruit, also known as National Fruit
24	*Artocarpus hirsuta*	Anjeli wood tree	Western Ghat, India	Rarely planted in forest as timber
25	*Bombax ceiba*	Simul tula, Red silk cotton	Malaya	Widely cultivated, wild for fiber and soft wood
26	*Borassus flabellifer*	Tal, Fan Palm	Central Africa	Wild and cultivated for fruit and juice
27	*Calliandra calothyrsus*	Calliandra	Indonesia	Occasionally planted for fuelwood and fodder

Sl. No.	Scientific name	Local/ English name	Origin	Status
28	*Cassia siamea (Senna siamea)*	Minjiri	South-east Africa	Cultivated and wild for fuelwood
29	*Casuarina cunninghamiana*	River she oak	Australia	Introduced for trial plantation but not promising
30	*Ceiba pantandra*	Pahari tula, Kapok tree	Tropical America, Andaman or Malaysia	Wild and occasionally cultivated for cotton and soft wood
31	*Chloroflora excelsa*	Chloroform, African teak	Tropical America/ Africa	Introduced as valuable timber (rare), only one tree is available in Lawachara forest
32	*Cicca acida*, Syn. *Phyllanthus acidus*	Arbori	Madagascar, Malaysia	Limited cultivation for fruit
33	*Cinnamomum camphora*	Korpur, Camphor	China, Japan	A rare cultivated tree
34	*Cocos nucifera*	Narikel, Coconut	Malaysia, Indonesia, Tropical America	Widely cultivated in the homesteads throughout the country
35	*Couroupita guianensis*	Canon ball tree, Naglingom	America	A rare ornamental plant
36	*Dalbergia latifolia*	Shisum	Southern India	Occasionally cultivated for timber, recent introduction by BFRI for field trial
37	*Dalbergia sissoo*		Eastern Himalaya	Widely cultivated for timber
38	*Delonix regia*	Sissoo, Shisum Krishna chura,	Madagascar	Occasionally cultivated as ornamental plant
39	*Diospyros discolor*	Gulmohur Bilati gab, Comogen	Malaysia, Fiji, Philippine	Widely cultivated for fruit
40	*Elaeis guinensis*	ebony Oil palm	Malaysia, South America	Planted for oil crop and avenue plant
41	*Eucalyptus alba*	Poplar gum	Australia	Limited to experimental plantation for timber and pulp
42	*Eucalyptus botryoides*	Southern	Australia	Limited to experimental plantation for timber and pulp
43	*Eucalyptus brassiana*	mahgony Cape York red	Australia	Limited to plantation for timber or pulp
44	*Eucalyptus camaldulensis*	gum Eucalyptus, River red gum	Australia	Wide plantation for fuelwood, pole and timber in private land but now the tree is banned!

Sl. No.	Scientific name	Local/ English name	Origin	Status
45	*Eucalyptus citriodora*	Eucalyptus, Lemon scented gum	Australia	Occasionally cultivated for timber or as ornamental trees
46	*Eucalyptus drepanophylla*	Eucalyptus	Australia	Limited to experimental plantation for pole and timber
47	*Eucalyptus grandis*	Flooded gum	Australia	Limited to experimental plantation for pole and timber
48	*Eucalyptus saligna*	Sydney blue gum	Australia	Limited to experimental plantation for pole and timber
49	*Eucalyptus tereticornis*	Forest red gum	Australia	Limited cultivation for pulp, pole and timber
50	*Eucalyptus urophylla*	Eucalyptus	Timor island	Limited cultivation for timber
51	*Garcinia mangostana*	Mangostan	Malaysia	Occasionally cultivated for fruit
52	*Gliricidia sepium*	Gliricidia	South America	Successful in trial plantations as nitrogen fixing, fodder and firewood species
53	*Grevillea robusta*	Silver oak	Australia	Occasionally planted as timber and avenue tree
54	*Guazuma ulmifolia*	----	Tropical America	Occasionally cultivated for timber
55	*Hesperethusa crenulata* Syn. *Limonia crenulata*	Kathbel, Elephant apple	Europe	Occasionally cultivated for sour fruit and timber
56	*Hevea brasiliensis*	Rubber, Para rubber	South America	Cultivated for latex and timber
57	*Kigelia africana syn. K. pinnata*	The Saussage tree	South Africa	Rarely cultivated as ornamental tree
58	*Lagerstroemia indica L.*	Pharash	Eastern Asia	Occasionally planted as timber
59	*Lagerstroemia speciosa*	Jarul	Myanmar, South east Asia	Wild and widely cultivated for timber and avenue
60	*Leucaena leucocephala*	Ipil-ipil, Leucaena	Tropical America	Wild and occasionally cultivated for fodder and fuelwood
61	*Litchi chinensis*	Litchu, Litchi	South China	Widely cultivated for fruit
62	*Madhuca indica*	Mahua	South India	Occasionally cultivated for flower and avenue
63	*Magnolia grandiflora*	Lily tree	North America	Occasionally cultivated for flower and avenue

2.5 The Benefits of the Introduction of Exotics

Successful plantation technologies have been developed in many countries (Evans 1992, Kanowski and Savill 1992). Light demanding, colonizing exotic species have been the most successful in monocultures under plantation management programs (Hughes 1994). The tropical and sub-tropical plantation forestry has focused on a small number of fast growing, colonizing species like *Acacia, Eucalyptus, Gmelina, Pinus, Populus* and *Tectona* (Evans 1992). These species have the ability to capture the site rapidly and tolerate harsh soil and climatic conditions and abuse from animals, human and fire, etc. These characteristics of exotics are a pre-requisite for success on the often highly degraded sites. Higher yield advantages of exotics over indigenous species have been attributed to their greater tolerance of degraded sites and their escape from specialized pests and diseases. Thus, the diminishing natural forest resources are being compensated by rapid expansion of planted exotic trees worldwide (Davidson 1995). Successful exotics are being planted in some other countries also, such as Spruce in Europe, Radiata pine in Australia and New Zealand, Ipil-ipil in Philippines and Australia, Eucalypts in India, China and Brazil (Evans 1992).

2.6 The Risks of the Introduction of Exotics

There is an increasing concern among foresters, ecologists, botanists, conservationists and policy makers about the threat of uncontrolled introduction of exotic tree species in the plantation programs. Invasion of exotics may cause major loss of biodiversity and species extinction either due to direct replacement by exotics or indirect effects on the ecosystem. Concern also exists on the degradation of the environment, e.g., the controversial effect of eucalypts on environment. There are also risks of the decline of growth and yield in second and successive rotations, or the infestation of pests and diseases, e.g., Psyllid in *Leucaena leucocephalla*, shoot borer in *Swietenia* and leaf defoliator in *Tectona grandis* (Hossain 2008).

2.7 Growth and Yield of Plantation Forests in Bangladesh

There has been a net loss of forest cover over the years in Bangladesh, and the net yield per ha of original planted area has dropped significantly (FMP 1992). The mean annual increment of present planting stock is extremely low in comparison to regional and international standards. There are also reports that 20-30% of all plantations established during the last 40 years have been destroyed, and of those surviving, the stocking is much less than the expected standards. The plantations appear likely to produce well below the capacity of the site due to lack of proper maintenance. All this has contributed to very low growth of 2.5 m^3 ha^{-1} yr^{-1} in areas, where 7.5 m^3 ha^{-1} yr^{-1} was the original standard (FMP 1992).

Teak, an economically important timber species initially found promising in the hill forest areas, but later on critics arose that it depletes soil fertility, prevents undergrowth and productivity depends on only suitable specific site conditions. Though the expectation of productivity was more than 7-8 m^3 ha^{-1} yr^{-1}, practically it is less than 2 m^3 ha^{-1} yr^{-1} in a wide range of plantations (FMP 1992). However, experimental plantations of

Eucalyptus camaldulensis showed excellent yield of 69 m^3 ha^{-1} yr^{-1} in a closed spaced plantation (Davidson and Das 1985), but in hilly areas the production reduced to as low as 14 m^3 ha^{-1} yr^{-1}. The growth behaviors of some plantations in the hilly area were erratic and poor throughout the rotation cycle, which may be due to the wrong selection of seeds and site. Similarly, *Acacia mangium* suffers from heart rot disease due to which the species is no more included in the new plantation programs (Basak 1997).

The remaining most commonly used species is the *Acacia auriculiformis*, which is widely planted and have shown success in degraded sites (Ara *et al.* 1989, Hossain *et al.* 1997). Hossain *et al.* (1998) reports the result of a provenance trial that leads to trees with single stems and good clear bole from a provenance trial in Chittagong University area. However, improvement for the clean cylindrical bole and other management practices will be needed immediately before going for large scale plantation programs of the selected provenances. Some *Acacia* plantations showed better survival and growth in different areas of the country and the yield is 15-20 m^3 $ha^{-1}yr^{-1}$ at 10-12 years rotation. Some other successful species, viz., pine, *gliricidia*, ipil-ipil are restricted to some localized plantations only (Table 2.5).

Table 2.5 Exotics proved successful in trials and their status in plantation programs

Species	Country of origin	Status in plantation programs
Acacia auriculiformis	Australia	Extensive plantation all over the country, but recently there is a restriction of this species for its controversial effect of pollen allergy. A natural hybrid of *A. auriculiformis* x *A. mangium* is getting priority in plantation programs for vigorous growth and yield
Acacia mangium	Australia/PNG	Successful plantations in Chittagong, CHT, Sylhet, Madhupur and North Bengal, but due to heart rot disease it is discarded from further large scale plantation programs
Acacia nilotica	India	Widely planted in North Bengal and coastal areas
Anacardium occidentale	South America	Limited plantations mainly for nut production
Dalbergia sissoo	India/Pakistan	Widely planted in North Bengal area, roadside plantations; but recently a devastating mortality has been noticed and farmers are reluctant to plant this species
Eucalyptus camaldulensis	Australia	Limited plantation in forests but widely in roadside and homesteads. Due to its controversial impact on site and other crops, the species is restricted in further planting in Government forest lands
Gliricidia sepium	South America	Successful in research trials but confined to limited plantations
Hevea brasiliensis	Malaysia	Widely planted in rubber estates of Chittagong, CHT, Sylhet and Madhupur sal forest areas

Species	Country of origin	Status in plantation programs
Leucaena leucocephala	Philippines	Successful plantation in North Bengal, coastal areas but sensitive to acid soils
Morus indica	India/ Pakistan	Planted in North Bengal area by Sericulture Board
Paraserianthes falcataria	Not known/ Molucca!	Widely planted as a lightwood species in Sylhet, Chittagong and Chittagong Hill Tracts
Pinus caribaea	Hondurus	Limited plantation in Chittagong and Sylhet forests but appears promising in Chittagong area
Swietenia macrophylla	Hondurus	Widely planted in forest plantations, homesteads, roadside plantations, Institute campus; Shoot borer problem at the early stage. BFRI is carrying out some tree improvement activities
Tectona grandis	Myanmar, India	Dominant species in plantation programs, but productivity is not optimum, required tree improvement programs
Xylia kerrii	Myanmar	Small scale plantation in Chittagong and Chittagong Hill Tract, Lawachara and Madhupur; growth is promising

Chapter 3

Introduction and Growth of Eucalypts in Bangladesh

3.1 Eucalypts in Their Natural Range

The Greek Words 'eu' means well and 'kaluptos' means covered, from where the name eucalypts derived. There are presently 789 recognized species of eucalypt, together with a further 123 subspecies or varieties, giving a total of 912 eucalypt taxa (Wilcox 1997). All but two of the 789 species occur naturally in Australia (Davidson 1995). However, according to the Australian National Herbarium of Australian National Botanic Gardens, there are some 800 species of *Eucalyptus*. The majority of these occur naturally in Australia with only a few species extending naturally into parts of Melanesia and the Philippines (Anon 2007).

3.2 Distribution of Eucalypts Outside Their Natural Range

In plantation programs of tropics and sub-tropics, eucalypts are often proved to be faster growing than other species and better survive on difficult or degraded sites. Concern exists that the eucalypts may not adequately provide forest benefits such as quality wood, soil and watershed conservation, wildlife habitat, or even recreational and aesthetic values, but there are hundreds of different eucalypt species with widely varying properties and uses (Table 3.1).

Table 3.1 Some uses of Eucalypts

Sl. No.	Use	Status
1	Wood	Fuel wood (also leaves and twigs from litter), construction timber, transmission poles, piles, railway sleeper, furniture, tools, curving
2	Altered and reconstituted wood	Pulp and paper, charcoal, carbon pellets, fiber board, particle board, ply wood, fabrics (rayon, and derivatives), wood cement composite board, compressed/ densified wood, films (cellophanes) and plastics
3	Volatile oil	1,8-cineol, alpha-pinene, beta-pinene, citronellol, geramiol, menthol, limonene, piperitone, thymol, roseol
4	Non-oil chemicals	Rutin, oxalic acid, tannins, terpenes, waxes, methanol, ethanol
5	Chemical and chemical applications	Throat lozenges, gargles, inhalants, candy, balms, burn, ointments, coloring dyes for yarn, phytohormones, perfumes, cosmetics, prickly heat powder, chewing gum, leather tanning, floatation of metal, paper coating, industrial solvents, gaseous and liquid fuels, ceramic additives, solvents (of resin, paints and varnishes), thinners and coagulants for drilling mud, spot and stain removers, nematicides, medicines, water reducing agent for cement

Sl. No.	Use	Status
6	Fodder	Fodder (leaves of a few species), fodder additives and animal growth promoters (powder).
7	Human Foods	Honey, water (from roots of some species), powdered roots, seed

Outside the natural habitat eucalypts were probably first grown in Portugal about 400 years ago, but the major plantings were started in Brazil in 1904 (FAO 1988). According to FAO (1988) the country had over 1 million ha of eucalypt plantations. Over 13 million ha of eucalypts now are estimated to be under plantation globally (Table 3.2). At present eucalypt planting around the world extends to about 80 countries and another 50 countries are in trial phases (Ali 1996).

Table 3.2 Eucalypts in the global forest plantation programs till 1990

Region	Total Area of Plantation (ha)	Eucalypts Plantation (ha)	Eucalypts Percentage
Africa	43,56,400	16,36,000	38
Mediterranean	-	9,20,000	-
Asia	712,81,600	60,20,000	8
1. India	189,00,000	48,00,000	25
Pacific	25,00,630	1,72,008	4
North America	-	1,10,000	-
Central America	3,45,000	93,000	27
South America	104,70,000	45,57,000	44
1. Brazil	70,00,000	36,17,000	52
Caribbean	3,83,000	37,080	10
World Total (In 74 countries)	894,36,630	135,45,088	15
India+ Brazil		84,17,000	63 (Worlds total)
Bangladesh	**2,70,000**	**12,000**	**4.5**

Recently numerous publications have provided detailed information on biogeography and ecology of the commonly planted *Eucalyptus* (Davidson 1995). References can also be made to some of the publications (Pryor and Johnson 1971, Pryor 1976, Florence 1996, Pryor and Johnson 1981 and Ovington and Pryor 1983). More details about eucalypts can also be found in other publications (Metro 1955, Jacobs 1955, Penfold and Willis 1961, Boland *et al.* 1980, Jacobs 1981, Boland *et al.* 1984, Hillis and Brown 1984, Lima 1984 and Chippendale 1988).

Little (1983), National Research Council (1983), Turnbull (1986), FAO (1988), Boland (1989) and Evans (1992) gave general information on *Eucalyptus* as exotics and the ecology of the Australian environment. Some of the regional studies on eucalypts include those for

Brazil (Lima 1987), Bangladesh (Davidson and Das 1985), Chile (Prado and Barros 1989), India (Sharma *et al.* 1984, Tewari 1992), and South Africa (Poynton 1979).

In the mid 1980's Poore and Fries (1985) published the FAO Forestry paper -59 on the "Ecological Effects of *Eucalyptus*" followed by some other technical and popular reports on the same subject (Davidson 1985a, 1985b, Florence 1986, FAO 1988, White 1988, Florence 1990, and ACIAR 1992).

3.3 Eucalypts in Forest Plantations of Bangladesh

In Bangladesh, like many other developing countries, eucalypts were introduced in the 19^{th} century as ornamental plants to decorate parks, road sides, or for collection in botanical gardens. Probably in the 1930's, *Eucalyptus citriodora* was introduced in the eastern part of Bangladesh by the tea planters as ornamental trees (Davidson and Das 1985). Later on, it spread throughout the country in a haphazard manner by botanists, foresters, gardeners and tree planters (Hassan 1994). The first trial of *Eucalyptus* was initiated by Bangladesh Forest Research Institute (BFRI) in 1965 and, seedlings were raised and planted in Rasulpur (Mymensingh) and Hathazari (Chittagong) but the results of the trial was not concluded with adequate information (Rashid 1969).

In Bangladesh, 84 seedlots of 12 species of *Eucalyptus* were imported from different parts of Australia through CSIRO in 1980's. From those only three species of *Eucalyptus,* viz., *E. camaldulensis, E. tereticornis,* and *E. brassiana* were found suitable in the climate and edaphic conditions of Bangladesh (Davidson and Das 1985, Hossain *et al.* 1989) through elimination trials. Another provenance trial of *E. brassiana* (12 provenances) established at the degenerated sal forest areas of Madhupur, Tangail was reported by Hossain *et al.* (1996a). However, the result of 1983 *E. urophylla* provenances trial in Tangail and Dinajpur claims the superiority of another *Eucalyptus* in Bangladesh (Islam *et al.* 1997). Another study on the coppicing ability of different provenances of *E. camaldulensis, E. tereticornis* and *E. brassiana* showed that their coppicing ability was very high and *E. camaldulensis* produces the highest coppice yield (Hossain *et al.* 1994). Some other provenance trials of *E. urophylla* (12 provenances) were laid out during 1983 to select the superior provenances in Bangladesh (Islam *et al.* 1997).

Similarly, the suitability of *Eucalyptus* was described by Banik and Alam (1995) at Sitakunda hilly regions of Chittagong Forest Division. Bhuiyan (1995) reported the potential of *Eucalyptus* grown in hilly regions of Chittagong to North Bengal agroforestry plantation and also in the degraded sal forest areas of central zone. The expected yield from eucalypt plantations in Bangladesh was 19 m^3 ha^{-1} yr^{-1}, though the silvicultural research station performance was exceptionally high (Davidson and Das 1985). Recently, studies showed that the actual yield per ha per year were only half of the expectations (Hassan 1994, 1995). However, Davidson *et al.* (1985a, b, c, d) determined the volume table, biomass production for young eucalypts in Bangladesh. Some plants, particularly in the hill forest areas of Chittagong and Cox's Bazar looked poor and erratic even within the same plantation throughout the rotation cycle. In Bangladesh, *Eucalyptus camaldulensis* was planted by the Forest Department and are being planted by private sectors owing to its proven capacity to supply fast grown timber for a wide variety of end uses. By 1995, some 12,000 ha eucalypt plantations have been raised in the forest land besides scattered plantings (area not known) in the farm lands, homegardens, strip plantations and ornamental plantings throughout the country (Bhuiyan 1995).

However, the seeds of a total of 218 provenances of 37 species of *Eucalyptus* were introduced in Bangladesh (Table 3.3) from which finally *E. camaldulensis*-Petford-1 was found suitable, promising and recommended for large scale plantation programs (Davidson and Das 1985).

Table 3.3 *Eucalyptus* species/ provenances introduced in Bangladesh for experimental plantations

Species	**Seed lot Number/ Provenances**	**Location of the provenances**
Eucalyptus acmenioides	8	New South Wales, Queensland
Eucalyptus botryoides	5	New South Wales, Victoria
Eucalyptus brassiana	18	Queensland, Papua New Guinea
Eucalyptus camaldulensis	25	Queensland, Victoria, New South Wales, Western Australia, Northern Territory
Eucalyptus citriodora	10	Queensland, New South Wales
Eucalyptus cloeziana	16	Queensland
Eucalyptus crebra	3	Queensland, New South Wales
Eucalyptus deglupta	1	Papua New Guinea
Eucalyptus delegatensis	1	New South Wales
Eucalyptus dives	1	New South Wales
Eucalyptus drepanophylla	1	Queensland
Eucalyptus exserta	5	Queensland
Eucalyptus fibrosa	1	New South Wales
Eucalyptus globulus	9	Tasmania, Victoria, New South Wales
Eucalyptus grandis	11	New South Wales, Queensland
Eucalyptus macrorhyncha	1	New South Wales
Eucalyptus maculate	9	New South Wales
Eucalyptus microcorys	3	New South Wales, Queensland
Eucalyptus microtheca	3	New South Wales, Northern Territory
Eucalyptus moluccana	4	New South Wales, Queensland
Eucalyptus oblique	1	New South Wales
Eucalyptus occidentalis	1	Western Australia
Eucalyptus pellita	3	Queensland
Eucalyptus pilularis	5	New South Wales, Queensland

Species	Seed lot Number/ Provenances	Location of the provenances'
Eucalyptus polybractea	1	New South Wales
Eucalyptus propinqua	1	New South Wales .
Eucalyptus radiata	1	New South Wales, Queensland
Eucalyptus resinifera	7	New South Wales, Queensland
Eucalyptus robusta	15	New South Wales, Queensland, Victoria
Eucalyptus saligna	18	New South Wales, Queensland
Eucalyptus smithii	1	New South Wales
Eucalyptus tereticornis	12	New South Wales, Papua New Guinea,
Eucalyptus tesselaris	1	Queensland
Eucalyptus tetrodonta	1	Queensland, Northern Territory
Eucalyptus torelliana	2	Queensland
Eucalyptus urophylla	12	Indonesia
Eucalyptus youmanii	1	New South Wales

Growth behaviour in many plantations was erratic and poor throughout the rotation cycle that disappoints the growers of planting eucalypts. It is considered that origin of quality seed sources is an important issue essential for the optimum growth of the species.

3.4 Silvicultural Features of Recommended *Eucalyptus* Species in Bangladesh

In Bangladesh, a total of 218 provenances of 37 species were introduced and planted experimentally; but only 4 species were found successful for future plantation programs (Das 1984b, Davidson and Das 1985, Hossain *et al.* 1997, Islam *et al.* 1997). Beyond these, *Eucalyptus citriodora* was the pioneer species introduced as an ornamental species in Sibpur Botanical garden, Kolkata and later on in different parts of India and Bangladesh (Zashimuddin *et al.* 1997). Considering the field performance of eucalypt species in Bangladesh, the following species were recommended for plantation programs.

3.4.1 *Eucalyptus brassiana* S.T. Blake

Eucalyptus brassiana is a small to medium sized tree (height range of 7-15 m) but can reach up to 30 m when site conditions are favourable (**Fig. 37**). It has rough, hard, dark-grey to almost black bark for a few meters, then turning smooth, whitish to yellowish above. Intermediate leaves opposite, ovate to orbiculate, straight, entire, dull grey green, sessile. Adult leaves disjunct, narrow lanceolate or lanceolate, falcate, acuminate, basally tapered, dull, green, thin, concolorous; petioles narrowly flattened or channelled. Lateral veins prominent, obtuse. Conflorescence is simple, axillary; umbellasters 3-flowered to 7-flowered; peduncles narrowly flattened or angular (to 3 mm wide).

The flowers are white, pedicellate, medium, and arranged in axillary umbels that are isolated. Each umbel has many flowers with pedicels or cylindrical peduncles. The hemispheric fruit measures 6 to 10 mm long, with a convex shoot and three valves. Fruits are globose or ovoid. Disc raised. valves exserted. Chaff dimorphic, linear and cuboid, chaff distinctly different in colour from seed.

This is a species occurring naturally in the Cape York Peninsula of Queensland and in southwestern Papua New Guinea. *E. brassiana* tolerates periodic water logging and is adaptable to a wide range of soil types including highly acidic soils. It is amenable in management as a short rotation coppice crop, and provides a useful, general purpose hardwood.

The wood of *E. brassiana* is used for pulp and in plywood and agglomerate boards. It is also used as crossbeams, long-lasting posts, and pilings and in construction, cabinet making, and general carpentry. Finally, it is used as a shade tree and in bee-keeping operations.

Seed collection and nursery raising for *E. brassiana*: The fruits are separated from the branches by hand or scissors and are placed in paper bags. They must be kept in well ventilated room to prevent attacks by fungi, and they should not be exposed to high temperatures. Fruits can be dried in the open air. When dried, the fruits quickly begin their dehiscence. Eucalypts, in general, produce a great quantity of seeds, which vary greatly in size, shape, and color. The ripened seeds can be kept viable for 5 to 30 years if they are stored in sealed containers at low moisture content (8 - 10 percent) and a temperature of 3 to 5 ^{0}C (Vozzo 2002). Before storing, the seeds must be treated to protect against insects and fungi.

The substrate for sowing seeds can be sand, vermiculite, or forest top soil. The substrate must be carefully sterilized before sowing. A simple sterilization method involves heating the soil in oven or using a 3% sulfuric acid solution in water, at a rate of 3 L m^{-2}. After the seeds are sown, the surface is covered with a thin layer of sand or fine soil, and watered again. Until the plantules finish emerging (10 to 20 days) the seed bed or germination trays must be kept in the shade; they can then be uncovered during the cooler hours. As they grow, they can be left under direct light and become ready for pricking out or dibbling. *Eucalyptus* is very susceptible to competition, especially from grass, the site should be cleaned.

Natural populations of *E. brassiana* found: Australia, Papua New Guinea.

Countries where *E. brassiana* planted: *E. brassiana* has proven successful as a reforestation species in a number of tropical countries but is usually over shadowed by faster growing provenances of *E. camaldulensis* and *E. tereticornis*. Exceptionally it is the fastest growing species on acid sulphate soils in the Mekong Delta of Vietnam. Hossain *et al.* (1996a) in Bangladesh reported the growth and biomass production of *E. brassiana* from 12 provenances.

3.4.2 *Eucalyptus camaldulensis* Dehn.

Common name: River red gum, red gum, river gum.

E. camaldulensis is a medium-sized to large tree (Doran and Turnbull 1997). It has the widest geographical range of any eucalypt and is extensively planted outside Australia. Its tolerance of extreme drought and high temperature, combined with rapid growth when water is available, deep penetration of roots, tolerance of periodic water logging and soil salinity, some tolerance of frost, good coppicing ability, and usefulness of the wood, are the keys to its success.

In Australia, *E. camaldulensis* commonly grows up to 20 m tall and rarely exceeds 50 m, while stem diameter at breast height can reach 1-2 m or more (**Fig. 38**). In open woodlands it usually has a short, thick bole which supports a large, spreading crown. In plantations, it can have a clear bole of up to 20 m with an erect, lightly-branched crown. The bark is smooth white, grey, yellow-green, grey-green, or pinkish grey, shedding in strips or irregular flakes (Tewari 1992). Rough bark may sometimes occupy the first 1-2 m of the trunk on *E. camaldulensis* var. *camaldulensis*.

Figure 37. *Eucalyptus brassiana*

Figure 38. *Eucalyptus camaldulensis*

E. camaldulensis can grow under a wide range of climatic conditions, from warm to hot and sub-humid to semi-arid. The mean annual rainfall in the natural range of *E. camaldulensis* is mostly 250-600 mm, although a few areas receive up to 1250 mm and some as little as 150 mm (Luna 1996).

Silvicultural characteristics: The success of *E. camaldulensis* as an exotic is attributed to its superiority in comparison to other trees in the production of wood on infertile dry sites, its tolerance of extreme drought and high temperature combined with rapid growth when water is available (Gibson *et al.* 1995), deep penetration of roots (Dawson and Pate 1996), tolerance of periodic water logging and soil salinity (Marcar *et al.* 1995, Sun and Dickinson 1995), some tolerance of frost (Awe and Shepherd 1975), good coppicing ability (Hossain *et al.* 1994), and usefulness of the wood (Midgley *et al.* 1989, Eldridge *et al.* 1993, Doran and Turnbull 1997, Doran and Wongkaew 1997). Considering salt tolerance, Marcar *et al.* (1995) classes *E. camaldulensis* as moderately tolerant with reduced growth at EC of about 5 dS/m or above and reduced survival about 10-15 dS/m. The species is illustrated by Boland *et al.* (1984), and Brooker and Kleining (1983, 1990, 1994).

Silvicultural practices:
E. camaldulensis is usually propagated from seed, though *E. camaldulensis* is one of several eucalypt species suited to mass vegetative propagation through stem cuttings (Eldridge *et al.* 1993). Das (1984a) describes the nursery raising procedures of *Eucalyptus* in Bangladesh (**Figs. 39, 40, 41 and 42**). There is about 700,000 viable seeds kg^{-1} of seed. As a rule-of-thumb, 1 kg of *E. camaldulensis* seed is sufficient to provide plants for 100 ha of plantation at a spacing of 3 x 2 m and typical seedling survival rates of 25%. Viability of seeds stored (5-8% moisture content) in dry air-tight containers in the refrigerator (3-5 ^{0}C) may be maintained for several years (Doran and Turnbull 1997). No pre-sowing treatment is required.

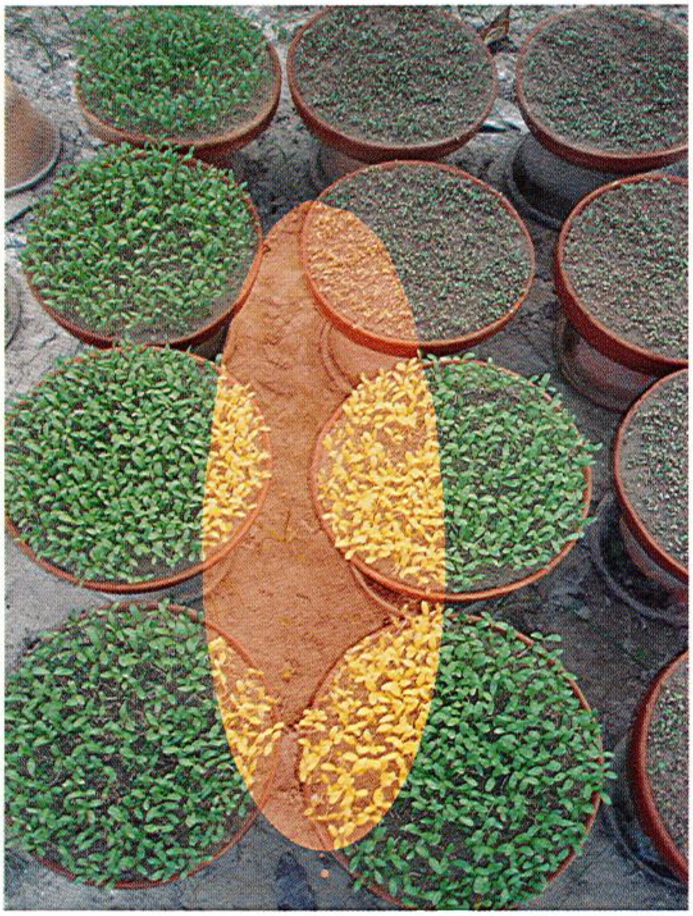


Figure 39. Eucalypt seeds sown in germination trays

Figure 40. Nursery owners also raised seedlings in nursery bed

Figure 41. Four weeks old Eucalypt seedlings in polybag

Figure 42. Tall seedlings preferred for roadside plantations

E. camaldulensis seed should be sown under shade on a free-draining and sterilized medium and covered with sand. Germination may be complete after seven days and than shade need to be reduced. Germinant are transplanted at the second leaf-pair stage to polybags filled with sterilized potting mix. Shade cover is needed for the first week after transplanting, after which plants should be exposed to direct sunlight gradually. Growth is fast under tropical conditions and plants could reach plantable size (30 cm) in six weeks, although 12-15 weeks is more usual. Occurrence of disease problems in the nursery can be limited by careful attention to hygiene, reducing watering and shade, and allowing good ventilation (Basak 1993).

E. camaldulensis is planted extensively for fire wood, small posts, shade, shelter, and amenity purposes (**Figs. 43, 44, 45 and 46**). *E. camaldulensis* is used in shelterbelts adjacent to crops where it offers protection from desiccating winds (Onyewotu and Stigter 1995). *E. camaldulensis* is useful for the reclamation of degraded lands, especially salt-affected land subject to seasonal water logging, and particularly when the salinity is moderate or low (Marcar *et al.* 1995, Sun and Dickinson 1995). It is used in mine site rehabilitation in Australia (Langkamp 1987). Fertilization, however improves the growth and development of eucalypts in early stages (Latif 1985, Paul and Ahmed 1995, Paul *et al.* 1998) in Bangladesh.

Figure 43. Young seedlings face competition with weeds in plantations

Figure 44. One year old saplings attain 3-4 meter in height

Figure 45. Growth variability is seen in plantations

Figure 46. Eucalypts became useable within 10-12 years age

E. camaldulensis is usually grown on short rotations and clear-felled at an age that maximizes production of logs of optimum size for a particular end use. This is usually a small-diameter material suitable for pulpwood, charcoal, or fuelwood. *E. camaldulensis* coppices well for five or more rotations. The season of felling affects coppice regeneration. Felling by saw to give a cleanly-cut short stump with minimum bark damage is the best for coppicing. Reduction of the number of coppice shoots on a stool is recommended (Evans 1992, Hossain *et al.* 1994). In Nepal, a single reduction to one shoot per stump at 3-6 months age is recommended (White 1986).

Spacing and cropping systems are variable, from community plantings around homes, villages, and along roads to closely spaced commercial plantations, and depend on the end-products required (Bhuiyan *et al.* 1986). When pulpwood is the principal objective, a spacing of 3 x 2 m (1667 stems ha^{-1}) is often used. Wider spacings of 4 x 2 m (1250 stems ha^{-1}) or 5 x 2 m (1,000 stems ha^{-1}) are recommended when larger trees are required. In Bangladesh 2m x 2m is the recommended spacing for woodlot plantation.

E. camaldulensis plantations are sometimes irrigated for maximum yields, e.g. unirrigated plantations of *E. camaldulensis* gave MAI of 20 m^3 ha^{-1} in 3 years compared with 50 m^3 ha^{-1} under irrigation. Good results from irrigation have also been achieved in Pakistan (Sheikh 1981). The ability of *E. camaldulensis* to compete with weeds is poor, frequent (3 times/year) and extensive weeding must be applied until the crowns close. Inadequate weed control may lead to failure of plantings. In Bangladesh manual weeding is the main means of controlling weeds.

Thinning schedules for *E. camaldulensis* plantations on longer rotations (20 years) for larger logs are given by White (1986), where an initial stocking of 700 stems ha^{-1} is reduced by conventional thinning of smaller diameter classes to 300 at five years, 200 at 10 years, 100 at 15 years, with clear felling undertaken at 20 years. *E. camaldulensis* naturally sheds its moribund branches readily such that artificial pruning is seldom necessary.

Management: High productivity of *E. camaldulensis* is reported in Israel under favourable conditions, e.g. growth of 70 $m^3ha^{-1}yr^{-1}$ in a four-year-old plantation in 3 x 2 m spacing on a fertile site with a controlled high water table (Zohar 1989). However, these conditions are rarely available in large scale plantations, and yields are generally much less.

In the drier tropics, yields of 5-10 m^3 ha^{-1} yr^{-1} on 10-20 year rotations are common, whereas in moist regions up to 30 m^3 ha^{-1} yr^{-1} may be achieved on 7-20 year rotations (Evans 1992). An MAI (mean annual increament) of 12 m^3 ha^{-1} over more than 20 years was recorded in Laos (Holmgren and Pettersson 1995). In southern Vietnam, overall yield for the species is 12 m^3 ha^{-1} yr^{-1} in four years, but better adapted provenances give yields of 20 m^3 ha^{-1} yr^{-1}. A fourfold increase in growth rate in less than 10 years was achieved in Brazil through tree breeding and better husbandry (Nambiar 1996). In Bangladesh closed spacing (1m x 1m) trial plantation produced 69 $m^3ha^{-1}yr^{-1}$ in 5.5 years (Davidson and Das 1985) and, Kibria *et al.* (1999) analyzed the financial return of *E. camaldulensis* from plantations.

Mycorrhizal association with eucalypt roots: *E. camaldulensis* roots form symbiotic mycorrhizal associations with various fungi. Ectomycorrhizal or dual ectomycorrhizal and endomycorrhizal (vesicular-arbuscular or VA) associations can occur in the genus (Brundrett *et al.* 1996). The trees derive certain nutrients (especially phosphorous) from the fungi through their roots to which the fungi are attached and, in turn, benefit from other nutrients available to them by the tree.

Protection: *E. camaldulensis* is susceptible to a diverse range of fungi causing damping-off, collar rot, and leaf diseases (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp., and *Cylindrocladium* spp.) in the nursery. Insects (e.g. termites and aphids) and rodents may be troublesome, and both physical and chemical control measures may be needed. *Colletotrichum gloeosporioides* has been found responsible for leaf spot and twig blight diseases of young *E. camaldulensis* plantations in Bangladesh, but was controllable by chemical sprays (Begum 1995). Similarly pink disease of *E. camaldulensis* was reported by Basak (1993) from Bangladesh.

***Eucalyptus camaldulensis* improvement activities:** Selection of the correct genetic material for the particular planting conditions is of paramount importance for *E. camaldulensis*. Tree improvement programs for *E. camaldulensis* were undertaken in many countries such as Australia, Brazil, China, India, Sri Lanka, Thailand, USA, Vietnam, and Zimbabwe. Breeding strategies for *E. camaldulensis* generally recommend starting with large base populations of seedlots from natural stands complemented by some locally selected material due to the uncertainty of the origins of local land races and the need to minimize inbreeding depression (Raymond 1991, Davidson 1993b, Doran *et al.* 1997).

E. camaldulensis tree improvement programs utilizing selection and mass propagation of clones exist in Bangladesh (Uddin 1996, Banik *et al.* 1997), Brazil (Nambiar 1996), India (Davidson 1993a, Kulkarni and Lal 1995), Nepal (White 1986), Morocco (Marien 1991), Thailand (Davidson 1993b), and Vietnam, and remarkable gains over short time spans have been achieved, e.g. over six years in Nepal (White 1986). Unfortunately the scientific advancements in eucalypts improvement remained confined to texts in Bangladesh and the use of local seed sources in plantation programs is very common.

Uses: The wood has a handsome red colour, a fine texture, and interlocking wavy grain. It is hard, durable, resistant to termites, and has many uses (Sattar and Bhattacharjee 1990, Sattar 1995). The wood is useful for furniture, construction timber, pulpwood, roundwood, and fuelwood (Poynton 1979). Preservation treatment is necessary for durability in the ground (Younus-uzzaman and Akhter 1999). The wood burns well and makes a good fuel, and is used as fuelwood in several countries (Jacobs 1981, Eldridge *et al.* 1993). Its dense structure and coppicing ability make it an excellent species for fuelwood production.

Some tropical provenances of *E. camaldulensis* (e.g., Petford) give 1,8-cineole-rich leaf oils and are potential sources of medicinal-grade *Eucalyptus* oils (Doran and Brophy 1990). Another major importance of *E. camaldulensis* in Australia as a source of honey, producing heavy yields of nectar in good seasons (Clemson 1985).

Country with natural populations: *E. camaldulensis* occurs throughout inland mainland Australia, typically along water-courses and on flood plains, but occasionally extends to slopes at higher elevations (Davidson 1993a).

Location of introductions: Globally, *E. camaldulensis* is perhaps the most widely used tree for planting in arid and semi-arid lands (Eldridge *et al.* 1993). Planting in the tropics, especially in South East Asia, Mexico, and Brazil, is increasing with the increased availability of the climatically-adapted northern Australian provenances (Midgley *et al.* 1989). In Thailand alone, some 300,000 hectares have been planted over the last ten years. In addition, there are extensive but largely unrecorded plantings of *E. camaldulensis* in many countries for shade and shelter.

3.4.3 *Eucalyptus citriodora* Hook.

Other names: *Corymbia citriodora* (Hook.) K. D. Hill & L. A. S. Johnson

Common name: Lemon-scented gum

E. citriodora is a medium-sized to large, straight tree, 25-40 m tall, handsome appearance, with smooth, pale grey, cream or pink, powdery bark throughout, decorticating in flakes **(Fig. 47)**. Foliage is fine, somewhat sparse in the crown and emits a strong lemon-scent after rain or when abraded. The lemon-scented leaves are characterized in identifying the species. Botanical descriptions of this species are provided under *C. citriodora* (Brooker and Kleinig 1994, Hill and Johnson 1995). More general accounts including illustrations are provided by Boland *et al.* (1984) and Anderson (1993).

Silvicultural characteristics: *E. citriodora* is a useful multipurpose tree for wood and oil, though it does not possess outstanding growth rate. However, it gives an acceptable growth on a wide variety of sites. *E. citriodora* is a lignotuberous species which is resistant to damage by fire. It can survive light frosts and is moderately drought tolerant; a minimum annual rainfall of 600 mm is generally required, and for rapid growth 900 mm is desirable. The species is susceptible to damage by typhoons or cyclones. Variable stem form, from straight to sinuous and frequent forking, and sparse foliage are less satisfactory characteristics of this species (Vozzo 2002).

Silvicultural practice: *E. citriodora* is generally propagated from seed and there are an average of 109,000 viable seeds per kilogram of seed and chaff mix (Turnbull and Doran, 1987). Seed germination rate varies from 30-50%. Seed is stored in dry state at 5-8% moisture content in air-tight containers in refrigerator (3-5^{0}C). Viability may be maintained for several years. No pre-sowing treatment is required. Rapid and complete germination is achieved under moist, warm (25-30^{0}C is optimal in the laboratory) conditions in the presence of light. Germination is epigeal.

The seeds may be sown directly into containers without pre-treatment, and covered with a thin layer of fine sand. A successful potting medium is a freely draining mixture of loam and sand that has been sterilized before use. Lignotubers develop early in the life of seedlings. *E. citriodora* is highly susceptible to damping-off and other fungal pathogens in the nursery.

Occurrence of disease in the nursery may be reduced by maintaining the hygiene, reducing watering and shade, and allowing good ventilation. Seedlings are planted out in the field when they reach a height of about 25 cm after 3 months of seed sowing.

Spacing varies with the purpose of the plantation. When grown solely for oil production with frequent coppicing, 3 x 1.5 m (2222 plants ha^{-1}) is appropriate. For fuelwood, poles or charcoal production with initial harvesting at seven years, a spacing of 3 x 2 m (1667 plants ha^{-1}) is commonly used. In India, several planting methods have proved economically favourable (Shiva *et al.* 1990).

E. citriodora is a light demanding species, that's why frequent and regular thinning is a prerequisite for healthy, vigorous plantations (Poynton, 1979). In China, this species is grown principally for poles and fuelwood on 20 year rotations, thinning is prescribed at age 3-5, 7 and 10-12; the first thinning reduces the initial stocking from 4,000 to 2,000 stems ha^{-1}, with two additional thinnings bringing the numbers down to a final stocking of 900 stems ha^{-1} (Turnbull 1981, Richardson 1990). Optimum rotation length depends on site and the end products. In Brazil, harvesting for wood production of the initial seedling crop is commonly conducted in the seventh year after planting (yield 110 m^3 ha^{-1}) to be followed by two coppice harvests at seven year intervals (yield 120 and 88 m^3 ha^{-1} respectively) (Ayling and Martins 1981). In southern China, the rotation length for *E. citriodora* plantations for roundwood, fuel and citronellal oil production is 20-21 years, after which the clear felled areas are replanted (Turnbull 1981).

In South Africa, stands of *E. citriodora* managed for sawn timber production are thinned at an intensity greater than 50%, four times in a 25-30 year rotation; thinning starts at 3-5 years with a stocking of 1370 stems ha^{-1} and reduces to a final stocking at the fourth thinning of 150 stems ha^{-1} at age 16 years (Poynton 1979). *E. citriodora* is a strongly self-pruning species.

Management: *E. citriodora* grows rapidly during its early years. A trial in Congo reached a mean height of 13 m in 4 years, and in Brazil a closely spaced planting grew to 15.5 m in 4.5 years (Gurgel Filho and Corsini 1973). In India, growth rates of 7 m in 9 years, 29 m in 20 years and 36.5 m in 24 years have been reported (Agnihotri *et al.* 1989). A mean annual height increment of 2 m is reported in southern African countries over the first five or even 10 years (Poynton 1979).

Mean annual increments (MAIs) in wood production of 12-15 m^3 ha^{-1} have been recorded in Africa, China and Brazil (FAO 1975, Ayling and Martins 1981), with a maximum of 25 m^3 ha^{-1} achieved on some sites in China (Richardson 1990). In Nigeria MAIs of 9.2 to 14.7 m^3 ha^{-1} has been reported (Adegbehin 1983). *E. citriodora* gave an average MAI of 20.5 m^3 ha^{-1} at four years on three sites in South Africa (Darrow 1997). While coppice production is concerned, the development of new growth from buds at the stump surface begins shortly after harvest, and within 10 months several shoots become dominant. At this point, rigorous thinning to 2-3 stems per stump is carried out (Ayling and Martins 1981).

Protection: *E. citriodora* has been damaged by a range of diseases including damping-off and leaf spots caused by *Cylindrocladium* spp., *Puccinia psidii* (a rust), and *Cryphonectria cubensis* (a stem canker) (Turnbull and Pryor 1984).

Uses: The wood of *E. citriodora* has a white or creamy sapwood; heartwood pale grey-brown to dark brown (Keating and Bolza 1982). Timber is hard, strong and tough. Air-dry density of wood from natural stands is about 1,000 kg m^{-3} with basic density of 800 kg m^{-3} (Bootle 1983). Physical and mechanical properties of wood were determined by Ali *et al.* (1974) and Kabir *et al.* 1995) in Bangladesh. It saws easily, planes well, but is rather difficult to nail, and prone to checking and collapses in drying. The timber of *E. citriodora* is used for general and heavy construction such as framing and bridge construction, flooring, tool handles, and case manufacture. *E. citriodora* is also widely used in park and avenue plantings as an attractive, large-sized ornamental tree noted for its bark colour, branching habit and glossy leaves. However, its crown is too sparse for shelterbelts.

E. citriodora is an important source of nectar for bees and yields a light amber honey (Clemson 1985, Blake and Roff 1988). The pleasant, lemon-smelling foliar essential oil of *E. citriodora* is widely used in less expensive perfumes (Weiss 1997). Its citronellal-rich (65-91%) oil is a preferred natural source of hydroxycitronellal, obtained by fractionation of the crude oil. It is used in perfumes and manufacture of menthol. The oil is also used in soaps and disinfectants; it has antibacterial (Pattnaik *et al.* 1996), antifungal (Baruah *et al.* 1996), and insecticidal functions (Trigg 1996 a, b).

Country with natural populations: *E. citriodora* is endemic to Queensland, Australia and is found mainly in open forest or woodland formations (Boland *et al.* 1984).

Introduction to other countries: *E. citriodora* has been extensively planted as an ornamental tree in many regions of the world, and has been planted for commercial purposes in many countries in Africa, South America, China, Fiji, India, South America and Sri Lanka (Penfold and Willis 1961, Streets 1962, Poynton 1979, Jacobs 1981, Booth and Pryor 1991, Davidson 1993b).

3.4.4 Eucalyptus tereticornis Sm.

Common names: Forest Red Gum

Eucalyptus tereticornis is a fast growing and widely planted tree species (**Fig. 48**). The species is marginally less drought tolerant than its close relative *E. camaldulensis*, but appears to be less susceptible to leaf pathogens and stem cankers when planted in areas of seasonally high humidity. *Eucalyptus tereticornis* is proving a valuable partner in various hybrid combinations with other fast growing eucalypts, including *E. grandis* and *E. urophylla*.

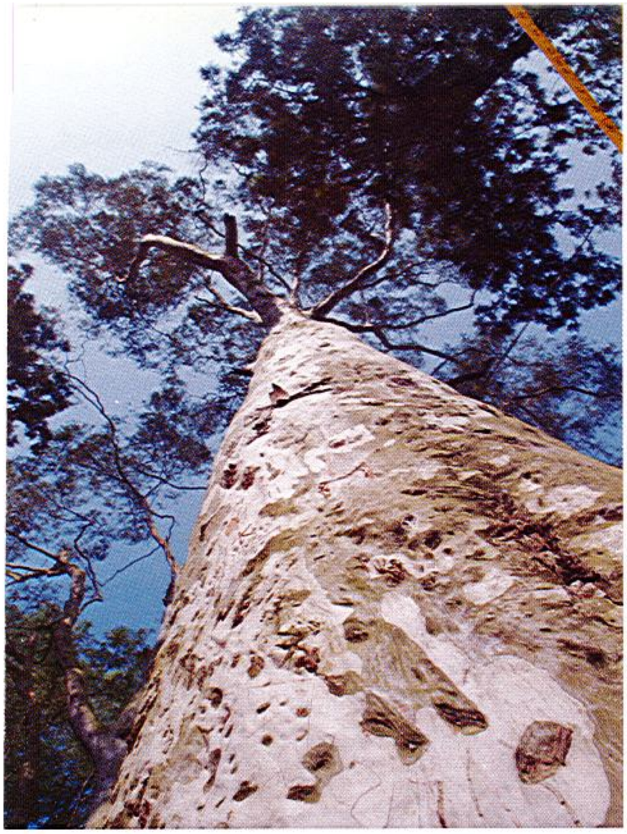


Figure 47. *Eucalyptus citriodora*

Figure 48. *Eucalyptus tereticornis*

Silvicultural practice: *Eucalyptus tereticornis* is usually propagated through raising seedlings from seeds. There are an average of 6,42,000 viable seeds per kilogram of seed and chaff mix (Turnbull and Doran 1987). No pre-sowing treatment is required. Rapid and complete germination is achieved under moist, warm conditions in presence of light. Germination is epigeal. Viability of seeds stored in dry condition at 5-8% moisture content in air-tight containers in refrigerator (3-5^0C) may be kept for more than 10 years (Boland *et al*. 1980).

Nursery practices for the successful raising of eucalypt planting stock are described generally in many texts including Jacobs (1981), Das (1984a, b), Tewari (1992) and Doran and Turnbull (1997). Seed sown under shade either directly to polybags or first in germination beds with seedlings transferred to containers at the second leaf-pair stage or at about 6 weeks from sowing (Foroughbakhch *et al*. 1997) is the general practice in preparing the planting stock.

Vegetative propagation: Vegetative propagation of *E. tereticornis* is relatively easy. Methods of vegetative propagation of *E. tereticornis* using stem cuttings are described in China (Zhong and Bai 1997) and India (Verma and Bagchi 1997). Micro-propagation of the tissues from bud, shoot or apex of stem has been carried out in China (Zhong and Bai 1997) and India (Jambhale and Patil 1996). Regeneration by stumps (coppice) has been successful in India (Chinnamani and Gupte 1966). In vitro clonal propagation of the hybrid, *E. tereticornis* x *E. camaldulensis* has been carried out in India (Chauhan *et al*. 1996).

Spacing and cropping systems are variable from community plantings around homes, villages and roads to closely spaced commercial plantations that depend on the end uses. When pulpwood and firewood are the principal requirements on a rotation of 5-6 years, a spacing of 1.5 m x 1.5 m is considered desirable in India (Tewari 1992).

E. tereticornis is intolerant of shade and does not compete well with grasses for water and nutrients. The usual practice of four weeding is to carry out in the first year, three in the second year and one during the rainy season in the third year. In grasslands of *Imperata cylindrica* in the Philippines, weeding is done every 3-4 months to obtain a seedling survival of 80-100% (Boer 1997). These operations may need to continue for up to 3-5 years after planting (Qadri 1983, Eldridge *et al.* 1993).

Rotation varies with site quality and management objectives. *E. tereticornis* is usually grown on a short rotation and clear-felled at an age that maximizes production of logs of optimum size for a particular end use (Jacobs, 1981). The duration of rotations used in some countries for small sized material is 9-12 years in Argentina, 5-7 years in the Congo, 6-10 years in India and 8-12 years in Uruguay; and for sawlog production 15-30 years in Pakistan with thinning every five years, and the rotation is 16 years in Uruguay with two thinning at 5-7 and 10-11 years (Forestry compendium 2005).

Plantations of *E. tereticornis* are expected to regenerate from coppice at least 3 times (Gupta and Raturi 1984). Coppice shoots attain a height of 4.6 m in one year in Pakistan (Qadri 1983). Reduction of the number of coppice shoots on a stool is a most important and time-consuming operation in coppice management (Evans 1992). A single reduction at 3-6 months to one shoot per stump is recommended for *E. camaldulensis* in Nepal and also applicable to *E. tereticornis* (White 1986).

Management: The mean annual increment (MAI) in volume over bark of *E. tereticornis* on medium quality sites at age 8-10 years in India was 15 m^3 ha^{-1} (Chaturvedi 1973). A review of species performance throughout India with volume tables is given by Tewari (1992), who showed a range in MAI's for 8-year-old plantations of *E. tereticornis* in India of 1.3-19.8 m^3 ha^{-1}, depending on stocking and site quality.

On an experimental site, the best provenances on the best sites in Bangladesh yielded over 60 m^3 ha^{-1} yr^{-1} after five years, at a planting rate of 10,000 stems per ha (Davidson and Das 1985). However, the plots were small and edge effects were not taken into account. About 30 m^3 ha^{-1} yr^{-1} production was reported from North Queensland (Eldridge *et al.* 1993). A 12 year old eucalypt species trial in northeastern Mexico gave a timber volume of 7.9 m^3 ha^{-1} yr^{-1} and firewood volume of 13.7m^3 ha^{-1} yr^{-1} (Foroughbakhch *et al.* 1997).

In Laos MAIs from trial plots with different spacings ranged from 11.8 to 44.6 m^3 ha^{-1} (Holmgren and Pettersson 1995). In a species trial in Guangxi province, China, MAI at 5.5 years of age for *E. tereticornis* was 11.3 m^3 ha^{-1}, although the better performing provenances reached 26.6 m^3 ha^{-1} in 4.4 years (Xiang *et al.* 1996).

Protection: One of the most serious diseases of *E. tereticornis* has been the canker caused by the fungus, *Corticium salmonicolor*, known as pink disease (Seth *et al.* 1978, Jacobs 1981, Sharma *et al.* 1985).

Hybrids: *Eucalyptus tereticornis* is of interest as a parent species in various hybrid combinations. In China, a seed orchard of the hybrid *E. urophylla* x *E. tereticornis* has been established in the field with different mating designs (Zhong and Bai 1997). There is also interest in India in the cross of *E. tereticornis* x *E. camaldulensis*.

Uses: Sapwood is pale, yellowish, and the heartwood is red, with a moderately fine texture and interlocked grain, hard, strong and durable. Density varies with tree age and environment. *E. tereticornis* is a major source of fuelwood, charcoal and timber for local use. It is also used for light and heavy construction, railway sleepers, bridges, piles, poles, mining timber, pulpwood, hardboard and particle board (Boer 1997). Indian Standards are available for the use of *E. tereticornis* timber for door frames, window shutters, furniture and cabinet making, tool handles and packing cases. Trees aged 14-15-years old with a girth of 1 m or more are regarded as suitable for sawnwood production (Tewari 1992).

Leaf extracts of *Azadirachta indica* and *E. tereticornis* used as a soil drench to reduce the number of root galls and egg masses of the root knot nematode, *Meloidogyne javanica*, in a tomato nursery in India was found successful (Vats *et al.* 1996).

Essential oils: The volatile leaf oils of *E. tereticornis* contained the monoterpenoids 1,8-cineole [eucalyptol] (0.1-33%), limonene (4-19%), alpha-pinene (1-27%) and beta-pinene (0.1-18%) as principal leaf oil components (Boland *et al.* 1991). *Eucalyptus tereticornis* is a major source of pollen in apiculture and produces a medium amber honey of distinctive flavour (Clemson 1985).

Country with natural populations: *Eucalyptus tereticornis* has the most extensive latitudinal range of any species in the genus. It occurs along the coast and on adjacent hills and plains of eastern Australia from eastern Victoria in the south to about Cooktown in far northern Queensland. *E. tereticornis* also occurs naturally in Papua New Guinea.

Location of introductions: *E. tereticornis* was one of the earliest eucalypts exported from the late nineteenth century as seed from Australia to various countries, viz., Pakistan in 1867, Ethiopia 1895, Zimbabwe 1900, Philippines 1910, Uganda 1912 (Zacharin 1978, Jacobs 1981).

Davidson (1988) identified *E. tereticornis* as the third most important plantation species in the tropics with an estimated plantation area of 780,000 ha in 1980. It is also an important reforestation species in Sri Lanka, China, Argentina, Bolivia, Brazil, Chile and Uruguay and in countries of central, southern and western Africa and the Pacific. The estimated area of *E. tereticornis* plantation in Brazil is 250,000 ha (Boer 1997). It is grown also in Greece, Italy, Portugal, Spain, and in Israel. It is of secondary importance for Bangladesh, Indonesia and Pakistan (Davidson 1993b).

3.4.5 *Eucalyptus urophylla* S. T. Blake

Common names: Timor mountain gum

Eucalyptus urophylla is a forest tree usually reaching 25-45 m in height with a dbh of 1 m, but it may attain a height of 55 m and a dbh of over 2 m (Eldridge *et al.* 1993). It has a straight bole for half to two-thirds of tree height.

Natural distribution: *E. urophylla* is one of the two species of eucalypts that does not occur in Australia. There are extensive stands of *E. urophylla* on the island of Timor. *E. urophylla* has the largest altitudinal range of any eucalypt ranging from 100-3,000 m above sea level. The species reaches its best development in natural stands between 1,000-1,500 m where, on deep well-drained soils of volcanic or metamorphic origins, it may grow to 55 m tall with a dbh of 2 m (Turnbull and Brooker 1978).

Country with natural populations: Timor island

Location of introductions: *E. urophylla* has been introduced in Brazil (Eldridge *et al.* 1993). Additional introductions have been made in Congo, France, Guyana, Australia, Papua New Guinea and North Vietnam. It has also been planted in China, Colombia, and a number of African and South-East Asian countries.

Silvicultural characteristics: *E. urophylla* is a vigorous light demanding species and growth is reduced with increasing weed competition. Under favourable conditions the species is able to attain a mean annual growth rates in excess of 30 m^3 ha^{-1} with proper provenances (Eldridge *et al.* 1993).

Silvicultural practices: The species is usually regenerated by seed and established using containerized planting stocks. Flowering usually starts within two years and seeds are produced abundantly within 4 years of plantation establishment. *E. urophylla* has an average 450,000 viable seeds per kilogram. Seed is orthodox and can be stored for extended periods at low humidity and temperature. Techniques for the collection, processing, testing and storage of *E. urophylla* seed are described elaborately by Boland *et al.* (1980).

Nursery establishment is generally done by sowing seeds in germination trays or nursery beds. The raised seedlings are transplanted into containers when they have two pairs of leaves. The potting medium is usually a free-draining loam-sand mix. Seedlings usually attain a plantable size of 25 cm in 10-12 weeks.

The species coppices readily (Higa and Sturion 1991) and is easily propagated by rooted cuttings (Huong 1993) or tissue culture (Le Roux and Staden 1991). In Brazil, *E. urophylla* or hybrids of *E. urophylla* and *E. grandis* are routinely raised using rooted cuttings derived from stump sprouts.

Management: *E. urophylla* grows fast and, under average conditions produces 20-30 m^3 ha^{-1} yr^{-1} of wood with bark at 5-10 years of age. The better provenances can yield up to 50 m^3 ha^{-1} yr^{-1} on favourable sites. High yields have been recorded in Brazil, Cameroon, Congo and Ivory Coast with good silviculture (especially weed control and fertilizer) and genetic improvement. Pegg *et al.* (1994) recorded a height of 20 m after 5 years in southern China, while Turvey (1996) measured 12 m after 2.5 years in Pulau Laut, Indonesia.

E. urophylla became the main species to be grown in plantations in Vietnam during 1989 with a total of 1,250 ha, compared with 600 ha of *E. camaldulensis* (Nghia 1996). The most promising provenances are from Mount Lewotobi and Mount Egon from Flores, Indonesia with increments of 15 m^3 ha^{-1} yr^{-1}.

Uses: The wood of *E. urophylla* is less dense than most eucalypts. The basic density is in the range of 540-570 kg m^{-3}. The heartwood is pinkish-brown to red brown and contains little gum. The wood is suitable for producing bleached chemical pulp and has good pulp yield (49.5%). The timber of older trees can be sawn and used for general construction purposes. In round boles, the wood is suitable for building poles and fence posts. The average annual volume increment is 20-30 m^3 ha^{-1} (Soerianegara and Lemmens 1993).

A range in oil yields was 1.1% (w/w% dry leaves) in the seedling leaves of *E. urophylla*. The bark has 10% tannin content (Soerianegara and Lemmens 1993).

3.5 Growth of Eucalypts in Plantation Forests

3.5.1 Growth of Some Tropical Plantation Species

Tropical and sub-tropical plantation areas were dominated by two genera: *Eucalyptus* and *Pinus*. Though there was a broad range (more than 100) of species utilized in plantations, but *Eucalyptus* accounted for 31.9% of the total hardwood plantation area. Other important species included *Acacia* spp., *Tectona grandis*, and *Gmelina arborea* (Table 3.4).

Eucalyptus species were planted extensively throughout the tropics and particularly in sub-tropical regions. The countries with the largest *Eucalyptus* plantation resources were India (31,00,000 hectares), Brazil (27,00,000 hectares), China (6,70,000 hectares), South Africa (5,57,000 hectares) and Viet Nam (4,83,000 hectares) and they accounted for 73% of the *Eucalyptus* resources (FAO 1988).

Table 3.4 Mean annual increments from various tropical plantations (first rotation)

Species	Location	m^3 h^{-1} yr^{-1}
Eucalyptus grandis	Brazil	60
E. urophylla	Brazil	60
E. camaldulensis	Cameroon	5 - 10
Gmelina arborea	Nigeria	15
Pinus caribaea var. *hondurensis*	Tanzania	40
P. caribaea var. hondurensis	Fiji	15 - 20
Tectona grandis	Tanzania	12
T. grandis	Bangladesh	2 - 3
T. grandis	India	2.5
Paraserianthes falcataria	Malaysia	20 - 30
Pinus patula	South & East Africa	15 - 20

3.5.2. Growth of Eucalypts in Plantation Forests of Bangladesh

E. camaldulensis, E. tereticornis and E. brassiana were proved superior to over 34 other Eucalypt species so far tried in Bangladesh (Davidson and Das 1985). With these species Petford, Mt. Garnet and Coen provenances respectively are the best provenances. After 5 years of growth, mean annual increment per hectare ranged from 11.7 to 95.6 m^3 for Petford, 4.9 to 66.6 m^3 for Mt. Garnet and 7.3 to 34.2 m^3 for Coen (Davidson and Das 1985). Latif (1985, 1988), Latif and Islam (2004), Latif *et al.* (1983, 1985a, 1985b, 1999) determined the biomass, volume and height diameter relations of eucalypts in Bangladesh. However, MAI in m^3 h^{-1} yr^{-1} of three superior *Eucalyptus* species at different silvicultural. research stations of Bangladesh Forest Research Institute at the age of 5-6 years are shown in Table 3.5. The growth and development of some woodlot plantations are shown in **Figs. 49, 50, 51 and 52.**

Table 3.5 Growth performance of 3 major Eucalyptus species (5 - 6 year old) in different research stations of Bangladesh Forest Research Institute, Bangladesh (Davidson and Das 1985)

Locality	Species	Survival %	Height (m)	dbh (cm)	MAI (m^3 ha^{-1} yr^{-1})
Lawachara, Srimongal	*E.camaldulensis*	56	8.8	4.8	17.1
Charaljani, Madhupur	*E.camaldulensis*	66	13.2	11.9	95.6
Charkai, Birampur	*E.camaldulensis*	84	7.9	5.6	23.4
Hathazari, Chittagong	*E.camaldulensis*	89	9.5	5.9	28.9
Keochia, Chittagong	*E.camaldulensis*	60	7.5	5.7	13.9
Lawachara, Srimongal	*E. tereticornis*	59	5.7	4.0	9.1
Charaljani, Madhupur	*E. tereticornis*	60	13.0	10.1	67.3
Charkai, Birampur	*E. tereticornis*	57	8.0	5.7	18.4
Hathazari, Chittagong	*E. tereticornis*	59	9.8	6.9	24.7
Lawachara, Srimongal	*E. brassiana*	61	8.7	4.9	15.3
Charaljani, Madhupur	*E. brassiana*	56	10.6	7.6	34.2
Charkai, Birampur	*E. brassiana*	76	8.1	6.0	16.3
Hathazari, Chittagong	*E. brassiana*	76	9.7	5.9	23.9
Keochia, Chittagong	*E. brassiana*	81	6.2	4.5	11.7

Figure 49. Eucalypt woodlot plantation in Chapainawabgonj and Sirajgonj

Figure 50. Eucalypt woodlot plantation at homesteads in Dohazari, Chittagong

Figure 51. Eucalypt woodlot plantation in Birgonj

Figure 52. Eucalypt woodlot plantation in Sitakunda, Chittagong

Similarly a species trial plantation in Madhupur, Tangail showed the superiority of eucalypts in comparison to some other species (Hossain *et al.* 1995) (Table 3.6). Surprisingly three

Table 3.6 Survival percentage, mean height (m) and mean dbh (cm) in a species trial at the age of 5.5 years in Madhupur, Tangail

Name of the species	Survival %	Mean ht. (m)	Mean dbh (cm)
Acacia auriculiformis	82a*	9.41a	9.1b
A. mangium	52bc	10.40a	11.5a
Albizia procera	-	-	-
Eucalyptus camaldulensis	83a	9.58a	7.0c
Prosopis juliflora	-	-	-
Artocarpus chaplasha	-	-	-
Chukrasia tabularis	06b	6.74b	6.8c
Dipterocarpus turbinatus	37c	3.72c	4.1b
Xylia kerrii	57b	7.09b	7.2c
Syzygium grande	59b	3.96c	4.1b

* Means denoted by the same letter(s) are not significantly different, Duncans Multiple Range Test (DMRT)

exotic species, viz. *A. auriculiformis*, *A. mangium* and *E. camaldulensis* showed maximum survival, height and diameter growth. *A. procera* and *A. chaplasha* did not survive at all because of tremendous grazing. Another trial of 12 provenances of 4 *Eucalyptus* species at Chittagong University campus showed the initial growth of 4 *Eucalyptus* species (Hossain et al. 1996b), where *Eucalyptus camaldulensis, E. tereticornis* and *E. urophylla* appeared as promising species (Table 3.7).

Table 3.7 Eucalyptus species-provenances seed lot no., origin, survival %, height and collar diameter at 1.5 years after outplanting in Chittagong University campus (Hossain *et al.* 1996b)

Species, Seed lot No. and Origin	Survival %	Height (cm)	Collar diameter (cm)
E. camaldulensis- 12355, Western Australia	81ab*	194.8 c	2.66 ab
E.camaldulensis- 15026, Victoria	56 c	197.0 bc	1.86 d
E. camaldulensis- 18604, Queensland	87 a	218.1 ab	2.73 ab
E. tereticornis- 14846, Queensland	65 c	175.0 e	2.17 c
E. tereticornis- 17864, Queensland	84 a	219.6 a	2.69 ab
E. tereticornis- 18760, Queensland	37 d	175.4d	2.15 c
E. Pellita- 18149, Queensland	81 ab	195.1 c	2.40 bc
E. pellita- 18749, Queensland	69 bc	146.6 f	2.16 c
E. pellita- 18759, Northern territory	75 ab	187.5 c	2.47 bc
E. urophylla- 13828, Indonesia	76 ab	175.2 de	2.91 a
E.urophylla- 17836, Indonesia	69 bc	182.4 cd	2.64 ab
E. urophylla- 18095, Indonesia	75 ab	156.1 ef	2.61 ab

* Means denoted by the same letter(s) are not significantly different, Duncans Multiple Range Test (DMRT)

In Chittagong University campus, another trial plantation was established with 15 multipurpose tree species of exotic and indigenous *(Acacia auriculiformis, Alstonia scholaris, Anthocephalus chinensis, Cassia nodusa, Casuarina equisetifolia, Chickrasia tabularis, Dalbergia sissoo, Eucalyptus camaldulensis, Gmelina arborea, Melaleuca leucadendron, Melia azedarach, Mesua ferrea, Pinus caribaea, Polyalthea longifolia and Terminalia arjuna)* in 1994 to find out suitable species for degraded hill areas of this region. The area is homogeneous in nature and a well representative of south-eastern hilly areas of Bangladesh.

Table 3.8 Survival % of 15 multipurpose tree species in the degraded hill soils of Chittagong University campus (± indicates standard error)

Species	**Origin**	**Survival (%)**
Acacia auriculiformis	Exotic	97 ± 2
Alstonia scholaris	Indigenous	78 ± 13
Anthocephalus chinensis	Indigenous	73 ± 14
Cassia nodusa	Indigenous	91 ± 7
Casuarina equisetifolia	Indigenous	92 ± 6
Chickrasia tabularis	Indigenous	86 ± 9
Dalbergia sissoo	Naturalized	64 ± 18
Eucalyptus camaldulensis	Exotic	98 ± 2
Gmelina arborea	Indigenous	96 ± 3
Melaleuca leucadendron	Exotic	100 ± 0
Melia azedarach	Naturalized	84 ± 12
Mesua ferrea	Indigenous	80 ± 14
Pinus caribaea	Exotic	82 ± 12
Polyalthea longifolia	Indigenous	74 ± 17
Terminalia arjuna	Indigenous	87 ± 10

All the plantation species were assessed for survival and growth annually and finally assessed at the age of 7 years (Hossain and Khan 2005). Analysis of data showed that the survival percentage was highest (100%) for *Melaleuca leucadendron* followed by *Eucalyptus camaldulensis* (98%), *Acacia auriculiformis* (97%) and *Gmelina arborea* (96%). *Dalbergia sissoo*, a naturalized species shows the lowest (64%) survivability (Table 3.8).

Growth and yield of the species: The tree growth parameters such as diameter at breast height, merchantable height, total height and crown diameter are shown in Table 3.9. *A. auriculiformis, E. camaldulensis* and *M. leucadendron* were superior in comparison to the indigenous species (Table 3.9). Among the indigenous species, *G. arborea, A. chinensis, C. tabularis,* and *C. equisetifolia* have shown better performance in respect to height and diameter growth. The height and diameter growth of *A. auriculiformis* (13.2 m and 16.6 cm respectively) and *E. camaldulensis* (14.1 m and 14.6cm respectively) in this study closely support the findings of Ahmed (1990) and Ara *et al.* (1989). It was found that some exotic species grow better than the tested indigenous species. This supports the findings of Bashir *et al.* (1989) in a 6-year old arboretum plantation of 29 multipurpose tree species. Similarly, *A. auriculiformis* and *E. camaldulensis* were found promising in the same area (Osman *et al.* 1992a, 1992b) and in Tangail (Hossain *et al.* 1995).

Table 3.9 Comparative growth performance of 15 multipurpose tree species in the degraded hill areas of Chittagong University campus

Species	Growth parameters			
	Dbh (cm)	**Merchantable height (m)**	**Total height (m)**	**Crown diameter (m)**
Acacia auriculiformis	16.6 a*	9.5 ab	13.2 ab	7.0 ab
Alstonia scholaris	9.5 c	5.4 bcd	6.5 cd	3.6 cd
Anthocephalus chinensis	14.2 ab	4.6 cd	7.5 bcd	6.2 abc
Cassia nodusa	12.1 abc	6.3 abcd	9.8 abcd	8.2 a
Casuarina equisetifolia	15.3 ab	9.6 ab	13.6 ab	6.1 abc
Chickrasia tabularis	12.5 abc	7.2 abc	11.3 abc	6.5 abc
Dalbergia sissoo	11.8 bc	7.8 abc	11.2 abc	4.7 bcd
Eucalyptus camaldulensis	14.6 ab	10.2 a	14.1 a	4.6 bcd
Gmelina arborea	15.4 ab	8.5 ab	12.2 abc	5.9 abcd
Melaleuca leucadendron	15.6 a	10.4 a	14.7 a	3.3 d
Melia azedarach	12.7 abc	5.6 bcd	9.4 abcd	6.2 abc
Mesua ferrea	8.8 c	3.5 d	5.5 d	3.6 cd
Pinus caribaea	11.7 bc	5.4 bcd	7.2 bcd	3.5 cd
Polyalthea longifolia	13.5 abc	3.2 d	5.8 d	4.7 bcd
Terminalia arjuna	11.2 bc	6.7 abcd	9.2 bcd	5.4 bcd

* Means followed by the same letter (s) are not significantly different at $P<0.05$, Duncan's Multiple Range Test (DMRT).

It is concluded that the investigation paved the way for selecting fast growing to moderately fast growing either exotic or indigenous tree species based on the initial growth performance in the degraded site. Out of 15, five species namely, *A. auriculiformis, C. equisetifolia, E. camaldulensis, G. arborea* and *M. leucadendron* have good and another five species namely, *A. chinensis, C. nodusa, C. tabularis, M. azedarach* and *P. caribaea* have medium growth performance over the remaining tree species growing at the same site. These multi-purpose tree species may be exploited to rejuvenate the degraded sites in the south-eastern hilly areas of Bangladesh.

A rapid assessment of some plantations raised by CARE and local government offices in char lands, haor and low lying flood plain areas showed eucalypts is not always growing faster in comparison to other species, but farmers preferred this species for its easy plantation techniques, non-palatability to grazing animals and early return of the benefits from plantations **(Figs. 53, 54, 55 and 56).**

Figure 53. Eucalypt as a roadside plantation species in Bogra

Figure 54. Eucalypt as a roadside plantation in Birgonj

Figure 55. Eucalypts are extensively used in roadside plantations in Chakoria, Cox's Bazar

Figure 56. Eucalypts in Chittagong - Dhaka highway at Sitakunda, Chittagong

Palima Khair Para roadside plantations in Tangail: The comparative initial growth performance of the roadside plantations showed that bokain, akashmoni, mangium are also growing faster in comparison to *Eucalyptus camaldulensis* (Table 3.10).

Table 3.10 Mean height (m) and dbh (cm) growth of Palima Khair Para Road plantations in Tangail at the age of 3 years

Species	**Mean ht (m)**	**dbh (cm)**
Mahgony- *Swietenia macrophylla*	3.54	5.7
Eucalyptus- Eucalyptus camaldulensis	5.80	9.1
Kanthal - *Artocarpus heterophyllus*	3.41	6.8
Akashmoni - *Acacia auriculiformis*	7.01	8.9
Jalpai - *Elaeocarpus robustus*	3.66	6.6
Bokain - *Melia sempervens*	5.49	10.5
Mangium - *Acacia mangium*	4.88	9.9
Acacia hybrid	3.66	9.7

Gopalpur - Syedpur roadside plantation in Tangail: Five kilometer road side plantations was established in 1997 with the following species of which *Eucalyptus*, akashmoni and sissoo are promising species (Table 3.11); *Acacia* appeared as the most promising species.

Table 3.11 Growth performance of Gopalpur - Syedpur roadside plantations in Tangail at the age of 7 years

Species	**Mean ht (m)**	**dbh (cm)**
Akashmoni - *Acacia auriculiformis*	9.00	16.8
Mangium - *Acacia mangium*	9.36	23.8
Sissoo - *Dalbergia sissoo*	9.66	17.2
Mahagony - *Swietenia macrophylla*	6.95	9.9
Eucalyptus - *Eucalyptus camaldulensis*	11.12	18.2
Bokain - *Melia sempervens*	7.65	13.6
Kanthal - *Artocarpus heterophyllus*	5.49	6.5
Jam - *Syzygium cumini*	5.33	8.7
Jalpai - *Elaeocarpus robustus*	4.88	7.0
Arjun - *Terminalia arjuna*	5.49	11.1
Melaleuca - *Melaleuca leucadendron*	8.53	12.2
Acacia hybrid	12.19	26.3

Kalihati Parkhi roadside plantations in Tangail: The roadside plantation was established in 2001 with a spacing of 2.0 m x 1.5 m. The height and dbh of the young trees are shown in Table 3.12. *Eucalyptus* plantation was a mixture of both *E. camaldulensis* and *E. tereticornis* seedlings. Bokain appeared as the most promising species because of their diameter growth.

Table 3.12 Growth performance of tree species at Kalihati Parkhi village in Tangail

Species	height (m)	dbh (cm)
Eucalyptus camaldulensis / E. tereticornis	6.6	8.4
Akashmoni - *Acacia auriculiformis*	5.6	8.0
Mahgony - *Swietenia macrophylla*	4.6	6.3
Bokain - *Melia sempervens*	5.9	11.2
Rain tree - *Albizia saman*	4.7	8.0

Saldah purbapara primary school in Sirajgonj: *Eucalyptus*, bokain, arjun, sissoo, rain tree and mango were planted in Saldah purbapara primary school compound in May-June 2003. The school compound is a raised land of 6' with an area of 0.66 decimal. Plantation was established in the slope of the raised land in four rows along with vetiber. Seedlings with a mean height of about 5' were planted in the of spacing of 1.5m x 1.5m. Raintree and sissoo saplings needed pruning to avoid excess branching and getting clear cylindrical bole. The people's preferable species were *Eucalyptus*, akashmoni, mahgony and bokain. Average growth performance of one year old seedlings was promising (Table 3.13). However, the homestead species in this area are litchi, kanthal, am, peyara, mahgony, jiga, *Eucalyptus*, akashmoni, tallah, simul and bariala bamboo, etc.

Table 3.13 Growth performance of one year old saplings in Saldah purbapara primary school, Kazipur, Sirajgonj

Species	height (m)	dbh (cm)
Bokain - *Melia sempervens*	2.9	3.6
Arjun - *Terminalia arjuna*	2.0	3.1
Sissoo - *Dalbergia sissoo*	3.9	4.5
Eucalyptus - Eucalyptus camaldulensis	4.1	3.8
Rain tree - *Albizia saman*	3.7	3.9

The roadside plantation species of Salgram dakkin para roadside (400 m road alignment) are *Eucalyptus*, bokain, raintree, arjun in 2 row plantations with a spacing of 1.8m x 1.8m. Grasses (kansh, binna) are also planted to check the soil erosion. Both sides of the road are paddy field. The total height and dbh of the saplings are shown in Table 3.14, where *Eucalyptus* attained both the maximum height and dbh.

Table 3.14 Total height (m) and dbh (cm) of one year old saplings at Salgram dakkin para road Kazipur, Sirajgonj

Species	**height (m)**	**dbh (cm)**
Eucalyptus - Eucalyptus camaldulensis	4.9	4.5
Bokain - *Melia semperverns*	3.8	3.2
Akashmoni - *Acacia auriculiformis*	2.7	2.8
Sissoo - *Dalbergia sissoo*	3.1	2.4
Rain tree - *Albizia saman*	2.4	2.8

Similarly roadside plantations at Jamtal Govt. primary school showed variable growth performance of the species at the age of 2 years (Table 3.15).

Table 3.15 Growth performance of roadside plantations at Jamtal Government primary school in Bogra

Species	**height (m)**	**dbh (cm)**
Sissoo - *Dalbergia sissoo*	4.7	5.4
Bokain - *Melia semperverns*	6.8	9.4
Mahgony - *Swietenia macrophylla*	4.6	5.0
Eucalyptus - Eucalyptus camaldulensis	5.3	6.4
Rain tree - *Albizia saman*	5.6	6.7

Roadside plantation of Azgar Ali Chairman Para, Bogra: Bokain, sissoo, mahgony, *Eucalyptus* and rain tree plantations each with 1200 seedlings show that both bokain and *Eucalyptus* are promising (Table 3.16). A small *Eucalyptus* block plantation showed variable growth performance which may be due to the variation of the quality of seedlings.

Table 3.16 Growth performance of the roadside plantations (2 yr old) in Azgar Ali chairman para Sariakandi, Bogra

Species	**height (m)**	**dbh (cm)**
Bokain - *Melia semperverns*	6.7	8.7
Sissoo - *Dalbergia sissoo*	5.1	6.5
Mahgony - *Swietenia macrophylla*	5.4	4.9
Eucalyptus - Eucalyptus camaldulensis	7.7	7.9
Rain tree - *Albizia saman*	6.0	7.4

Mustafir Hat Burirbazar Sarak plantation, Lalmonir Hat: About 2,100 seedlings were planted in 2001. Survival percent was very promising (92%). At present the Gukunda union parishad is looking after the plantations. The species planted were kanthal, mahgony, eucalypts, akashmoni, ipil-ipil, bokain and kala koroi. Growth variation is remarkable (Table 3.17).

Table 3.17 Growth variation of Mustafir hat Buribazar sarak plantation at Lalmonirhat (2 year old plantation)

Species	**height (m)**	**dbh (cm)**
Eucalyptus - *Eucalyptus camaldulensis*	6.1	8.0
Mahgony - *Swietenia macrophylla*	3.4	5.2
Bokain - *Melia sempervens*	5.7	6.7
Akashmoni - *Acacia auriculiformis*	5.9	8.7
Ipil-ipil - *Leucaena leucocephala*	5.5	6.2
Kanthal - *Artocarpus heterophyllus*	4.0	7.2
Jam - *Syzygium cuminii*	2.7	4.9
Sil Koroi - *Albizia procera*	5.8	9.8

In another 2 year old plantation of fast growing species in Saptabari roadside in Lalmonirhat, bokain attained the maximum height followed by *Eucalyptus* (Table 3.18).

Table 3.18 Growth performance of 2 year old saplings of R1/13 plantation at Saptabari, Lal Monirhat

Species	**height (m)**	**dbh (cm)**
Bokain - *Melia sempervens*	6.5	8.0
Eucalyptus - *Eucalyptus camaldulensis*	6.2	5.7
Mahgony - *Swietenia macrophylla*	4.4	4.0
Ipil-ipil - *Leucaena leucocephala*	5.3	6.2
Kanthal - *Artocarpus heterophylla*	3.4	4.6
Jam - *Syzygium grande*	2.0	3.0
Rain tree - *Albizia saman*	3.7	3.5
Sissoo - *Dalbergia sissoo*	3.7	4.8
Jalpai - *Elaeocarpus robustus*	2.7	4.7

Ishwardi BUILD R1/25 (Pabna rice mill to Sariakandi road): Both the sides of 2.13 km road extending 3.55 km were planted with 2,130 seedlings. The spacing was of 2m x 2m. The growth data of the seedlings revealed that *Eucalyptus* attained the maximum (7.3 m) height, whereas, rain tree and ipil ipil attained the maximum dbh at the age of two (Table 3.19).

Table 3.19 Growth of the saplings of alignment at Ishwardi BUILD R1/25 (Pabna rice mill to Sariakandi road)

Species	**height (m)**	**dbh (cm)**
Rain tree - *Albizia saman*	5.8	14.1
Mahgony - *Swietenia macrophylla*	5.5	6.1
Ipil-ipil - *Leucaena leucocephala*	6.5	11.5
Jam - *Syzygium grande*	4.0	5.7
Arjun - *Terminalia arjuna*	3.2	6.8
Bokain - *Melia sempervens*	6.6	10.8
Eucalyptus - *Eucalyptus camaldulensis*	7.3	10.6
Kala koroi - *Albizia lebbeck*	4.6	10.9

Eucalypts are popularly planted in homesteads **(Figs. 57, 58, 59 and 60),** croplands **(Figs. 61, 62, 63 and 64),** and pond bank **(Figs. 65 and 66)**. Since eucalypts are able to grow in both waterlogged and dry areas, opportunity exists to increase the area of the plantations **(Figs. 67 and 68).** Eucalypts performs best in mixed plantations **(Figs. 69 and 70).** In some areas, eucalypts also dominates in homestead vegetation composition **(Figs. 71 and 72).**

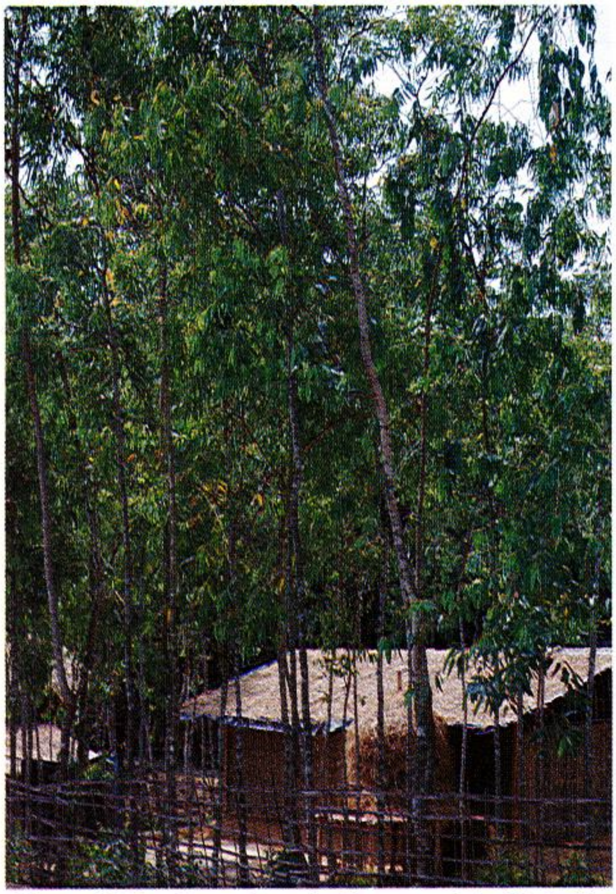


Figure 57. Eucalypts planted at homesteads in Chakoria

Figure 58. Eucalypts becoming dominant in homestead vegetations

Figure 59. Farmers are interested for planting Eucalypts in North Bengal

Figure 60. Eucalypts are extended to an off-shore island - Kutubdia

Figure 61. Eucalypts planted as a hedge-row in cropland of Bogra

Figure 62. Eucalypts planted in cropland boundaries in Birgonj

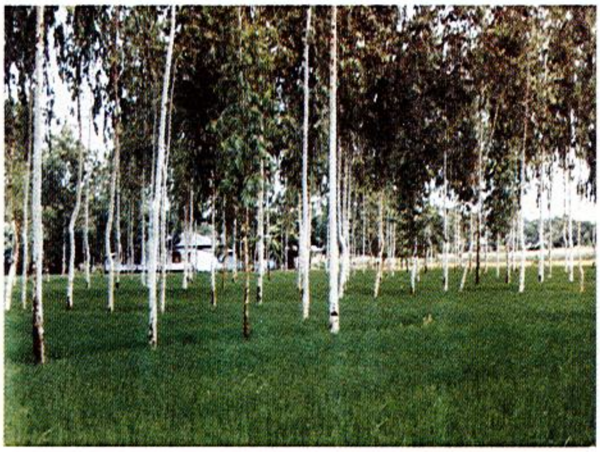


Figure 63. Eucalypts planted in cropland in Ghora ghat

Figure 64. Eucalypts in marginal lands of paddy fields

Figure 65. Eucalypts grown at pond bank in Sitakunda, Chittagong


Figure 66. Eucalypts at pond bank in Mirersorai, Chittagong


Figure 67. Eucalypts are able to grow in seasonal flooded area at Satkania, Chittagong


Figure 68. Eucalypts can also grow in drought areas of Dinajpur


Figure 69. Eucalypts grow faster than Mahgony in a mixed plantation at Sitakunda, Chittagong

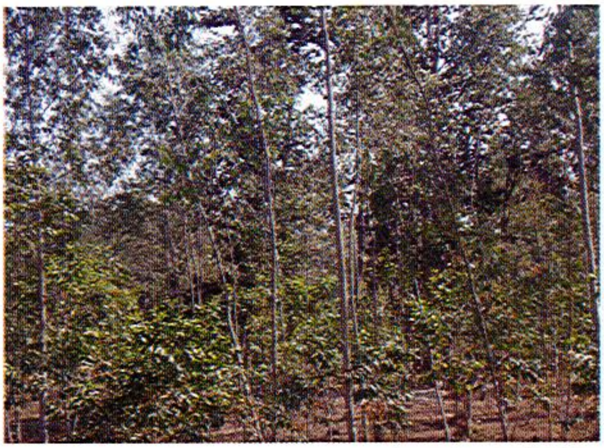


Figure 70. Selected seed sources of Eucalypts also grown faster than Akashmoni


Figure 71. *Eucalyptus* is the dominant species in homesteads

Figure 72. Homestead with eucalypts bring significant return within 5-6 years

3.6 Coppicing Ability of Eucalypts

Eucalypts possesses excellent coppicing ability **(Figs. 73 and 74)** and first few generations are more productive than the seedling crops (Latif *et al*. 1985). A comparative study of the coppicing ability of different provenances of *E. camaldulensis, E. tereticornis and E. brassiana* in Charaljani Silvicultural Research Station, Madhpur, Tangail showed that their coppicing ability was very high (Table 3.20) and, *E. camaldulensis* produces highest coppice yield (Hossain *et al*. 1994).

Table 3.20 *Eucalyptus* coppice crop at Charaljani Silvicultural Research Station, Madhupur, Tangail at the age of four year (Hossain *et al*. 1994)

Species	Stumps Coppicing (%)	Coppice stocks (stems ha^{-1})	Height (m)	DBH (cm)	Stem volume over bark (m^3 ha^{-1})
E.camaldulensis	95	6733	11.5	11.0	86.0
E. tereticornis	95	5371	10.9	10.2	59.5
E. brassiana	95	5432	8.7	7.5	30.8

Figure 73. Profuse coppice shoots develop after felling the *Eucalyptus* trees

The coppicing method of regeneration utilizes the exceptional early growth rates of stump sprouts or root suckers exhibited by eucalypts (Blake 1980, 1983), and offer an outstanding scope for the production of fuelwood, poles and pulp through regeneration of coppice shoots from the cut stumps (Hummel 1989, Pereira *et al.* 1989). However, the ability of coppice declines with the age. The coppicing ability may also vary with the environmental conditions at the time of felling (Jacobs 1955, Cremer 1973, Grunwald and Karschon 1974).

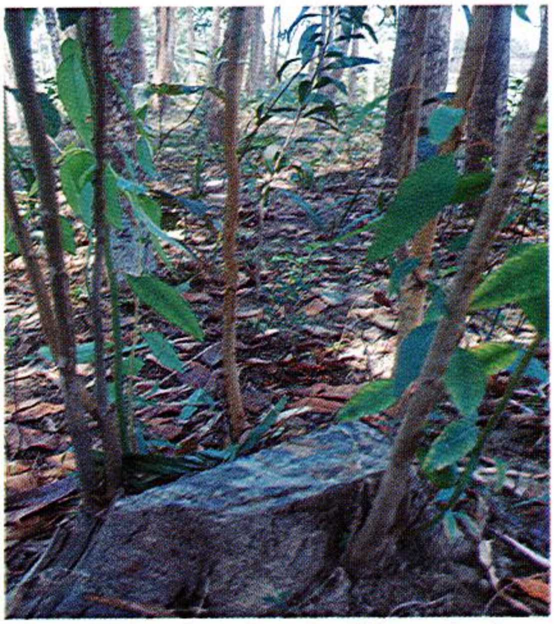


Figure 74. Few shoots have the ability to develop young trees very quickly

Chapter 4

Controversy and Criticisms of *Eucalypts* Grown as Plantation Species

Though eucalypts have become important industrial species in many countries, debate still remains about their effect on the environment; objection to large scale planting is very intense in India (Karanth and Singh 1983, Shiva and Bandyopadhyay 1983). However, the current expansion rate of eucalypt around the world shows that not all the countries embarking in large scale plantations are convinced by concerns raised in India.

This controversy has resulted in confusion about the suitability of eucalypt plantations in Bangladesh. Research results suggest that some provenances of several species of the genus *Eucalyptus* are suitable for the country in terms of growth and site adaptability. As a result the country has undertaken a large scale eucalypt planting program, and about 12,000 ha eucalypt plantation were established to supply domestic fuelwood. Very few research projects have yet been undertaken to verify objections under Bangladesh conditions. In some cases, it is assumed that the effects in Bangladesh are the same as those in India. As a result, a negative attitude towards eucalypt planting has developed among policy makers, politicians and environmentalists. The news media and environmentalists published articles on the possible bad effect of these species in Bangladesh and neighboring countries. There is a directive from the government not to plant these species further more (Letter of Ministry of Environment and Forests No. (Gen-3)50/93/250 of dated 18.04.1995). In extreme cases, some established plantations of Forest Deportment were felled or cleared off also. *Eucalyptus* is blamed to absorb more water, reduce soil fertility, cause soil erosion, be harmful for wildlife and reduce native understorey vegetation diversity than other species. But, the criticisms and blames are not supported by sufficient scientific research findings. Contrary, the leading forestry, agroforestry experts and scientists concluded that eucalypts may be a suitable species for afforestation and reforestation in denuded areas, marginal lands, roadside plantations and agroforestry programs (Amin *et al.* 1995, Hossain *et al.* 1997).

However, the mass of rural people who plant eucalypts on their homesteads have not shown any negative reaction to these environmental whims. These people participate in tree planting in small rural woodlots, agroforests and marginal land in rural areas (Ahmed *et al.* 2007b). An early return of a handsome volume of wood is very important to them. They are in crucial need of fuelwood, poles and posts for domestic uses (Ahmed and Akhter 1995). So, a sharp divergence of opinion exists between different groups of people in the society. Therefore, there are some findings both in favor and against of *Eucalyptus* plantings in Bangladesh. Some of the controversies are discussed here.

4.1 Excessive Water Consumption

It is claimed that eucalypts consume more water in comparison with other species, which results into drying of site and converting the site as unsuitable for the growth of other crops. It is true that eucalypts are known to be highly water demanding. This is mainly because of their rapid growth (Davidson 1995). Though the apparent water consumption efficiency of eucalypts is much higher in comparison to many native species (Table 4.1), the net consumption on unit weight of dry matter produced is less (Chaturvedi 1983, Tiwari and Mathur 1983). On the contrary, eucalypts actually economise soil water storage because of having minimum evapotranspiration surface, waxy leaves, stems and fewer lenticels (Karschon and Heth 1967, Banerjee 1972). Dabral (1970) conducted a study on potted seedlings of several forest species (*Eucalyptus citriodora, Dalbergia* sp., *Pinus* sp., and *Populus* sp.) and concluded that eucalypt was producing more biomass per unit weight of water consumed, though its apparent water consumption was greater than other genera.

Table 4.1 Comparison of water use efficiency of some plant species in India (Chaturvedi 1983, Tiwari and Mathur 1983)

Species	Biomass L^{-1} of Water	Water L g^{-1} Biomass
Eucalyptus hybrid	2.06	0.48
Sygygium cumini	2.00	0.50
Albizia lebbeck	1.83	0.55
Acacia auriculiformis	1.39	0.72
Dalbergia sissoo	1.31	0.77
Pongamia pinnata	1.13	0.88

However, in another experiment done in the Institute of Forestry and Environmental Sciences, University of Chittagong, *Aphanamaxis polystachya* was found more water consuming species considering per unit volume increment in comparison to *Eucalyptus camaldulensis* (Table 4.2).

Table 4.2 Average volume increment and average water per unit volume required by growing seedlings of *E. camaldulensis*, *T. arjuna*, *A. polystachya*, *S. mahagoni* and *A. auriculiformis* in 45 days grown in the propagator house

Species	Average volume increment (cm^3)	Average water consumption (ml)	Water per volume increment (ml cm^{-3})
E. camaldulensis	0.33	1,042	3,145
T. arjuna	0.26	734	2,824
A. polystachya	0.12	544	4,233
S. mahagoni	0.45	740	1,615
A. auriculiformis	0.42	985	2,323

According to news in the daily newspaper (The Daily Star, 8.11.2007) the Soil and Water Science Department of Hajee Danesh Science and Technology University (HSTU) in Dinajpur has recently found that excessive number of *eucalyptus* in some areas are adversely affecting local water tables and causing water shortage. According to the report, if *Eucalyptus* is allowed to grow around a natural reservoir for about 10 years at a number of 10 percent of total trees, water level is likely to reduce by 20 percent. However, the research methodology and its limitations were not mentioned in the report. In response to these findings, experts suspected limitations in the experimental design. Forest Department has been suggesting to plant eucalypts in mixture with other species instead of monoculture since this species was introduced in Bangladesh in mid-eighties. The Ministry of Environment and Forest in 2002 attempted to impose a ban on eucalyptus plantation. But eventually, it just imposed a restriction that *Eucalyptus* plantation must be within 10 percent of the total forest as per the suggestion of Bangladesh Forest Department (BFD). Though it is claimed that *Eucalyptus* consumes more water than other indigenous species (Ahmed and Akhter 1995), another study at the Forest Research Laboratory, Kanpur, India showed that *Eucalyptus* actually appears to be more efficient in water use than other 'useful' native trees (Table 4.3).

Table 4.3 Water use efficiency or water consumption per unit of biomass produced (Prabhakar 1998)

Species	Litters gram^{-1}
Eucalyptus species	0.48
Albizia procera	0.55
Dalbergia sissoo	0.77

In one year, total biomass produced in eucalypts is greater than many of the slower growing native species (Prabhakar 1998). Prabhakar (1998) claim that in an eight year rotation plantation, the mean annual growth of *Eucalyptus* is about 8 m^3 ha^{-1}. It is also known to reach as much as 40 m^3 ha^{-1} while for indigenous trees the average is 0.50 m^3 ha^{-1}. The high productivity therefore, necessitates a greater water demand. Another study (cited in Saxena 1994) supports this supposition.

4.2 Depletion of Soil Nutrients

Eucalyptus is frequently blamed for its adverse ecological effects in particular its contribution in depletion of soil nutrients. However, the fact lies that it is impossible to provide a full introduction of Eucalypt's contribution to soils and the nutrient cycle before getting experimental results on the effects of *Eucalyptus* to the soils. Singhal *et al.* (1975) reported that *Eucalyptus* litters humify rapidly, and the humified materials incorporate into the surface soil more rapidly and translocation of more humified materials to lower depths is more pronounced under *Eucalyptus* plantation compared to sal plantation. A substantial enrichment of nutrients in the *Eucalyptus* litters is reported by George (1978, 1979, 1982) and Sharma *et al.* (1984). Davidson (1973) reported that *Eucalyptus* can accumulate nutrients in top soil from the deeper horizons through nutrient pumping mechanism. As a result Davidson suggested *Eucalytus* planting for degraded lands for one or two rotations to take advantage as a good strategy to improve soil condition. Srivastava *et al.* (2003) acknowledged that some psuedo-environmentalists started advocating strong propaganda, though not based on scientific research that, *Eucalyptus* dries out the sub-soil water, consequently lowering the water table.

With a view of having decisive effect on land use pattern of agroforestry, which has suffered a setback, Mathura and Billhaur investigated field plantations of *Eucalyptus tereticornis* (*Eucalyptus* hybrid) of various age groups at two different sites during the year 1995-1997. They concluded that there was significant variation in soil moisture within the soil depths and also between the months at both the sites. The soil moisture at different depths under *Eucalyptus* plantation of various age groups was higher at Billhaur site compared to Mathura in respective soil depths. The similar trend was observed in control of respective sites. The study revealed that it is the edaphic factors especially soil texture including environmental conditions, which play an important role in variation of soil moisture level. Thus, the myth that *Eucalyptus* species dry up the sub-soil moisture, thus lowering the water table, proves to be categorically unscientific.

Aryal *et al.* (1999) studied the effect of mixed planting of *Eucalyptus camaldulensis* and *Albizia procera* on the soil fertility compared to their mono-plantation in Bangladesh (Table 4.4). They found that both the species performed well in mixed condition compared to the mono-plantation. The soil in mixed plantation showed better nutrient contents compared to their single plantations. They suggested mixed plantation for improving soil properties. Therefore, based on the misinformation it would be an inappropriate decision for any authority to eliminate a high yielding species from the plantation program. The best option would be to keep it controlled in mixed plantation and trying to explore its best contribution **(Fig. 75 and 76)**.

Table 4.4 Soil p^H, electrical conductivity (EC), and contents of soil nutrients in pure and mixed planting plot of *Eucalyptus camaldulensis* and *Albizia procera* at Chittagong University campus (Aryal *et al.* 1999)

Treatments	p^H (H_2O)	EC ($dS\ cm_1$)	T-N	T-P	OM	Av-P	Av-K	Ca	Mg
			-------------$g\ Kg^{-1}$		----------	-----$mg\ Kg^{-1}$-----		-------$g\ Kg^{-1}$------	
P_1	5.13	0.39	0.62a*	0.73a	3.86a	1.06a	14.73a	0.47a	2.64a
P_2	6.21	0.62	1.26d	1.34d	8.01d	3.99c	39.34c	0.95bc	7.63c
M_1	6.38	0.56	0.87bc	1.11c	6.21bc	3.71c	41.23c	1.12c	6.63c
M_2	5.94	0.49	0.83b	0.82ab	4.81ab	2.07b	22.05b	0.86bc	6.24bc
M_3	6.12	0.52	0.97c	0.98bc	7.83cd	3.51c	26.80b	0.73ab	4.25ab

* Values in the column not followed by the same letter(s) are significantly different ($P<0.05$)

(P_1- *Eucalyptus* only, P_2- *A. procra* only, M_1-50% Euc.+50% *A. procra*, M_2-75% Euc.+25% *A. procra*, M_3-25% Euc.+75% *A. procra*)

Figure 75. Established ground vegetation in Eucalypts plantation protects soil erosion

Figure 76. Eucalypt mixed plantation conserve soil, water in plantations

Eucalyptus spp	Allelochemical source	Target Species	Basis	Reference
E.camaldulensis	Leaf litter in Germination tray	*Vigna unguiculata, Cicer arietinum, C. cajan, Albizia procera* and *Leucaena leucocephala*	Bioassay	Not published (IFES)
E. crebra		Various species	No data	Story 1967
E. dawsonii		Various species	No data	Story 1967
	Roots,leaves, litter	Autotoxic	Pot trial	Bowman and Kirkpatrick 1986
		Autotoxic	No data	Costin 1954
E. drepanophylla		Autotoxic	Pattern	Rotheram 1983
E. elata	Litter	*Lemna*	Bioassay	May and Ash 1990
E. fraxinoides		Autotoxic	pattern	Prober 1992
E. globules	Litter, stemflow, roots lechate, oils	Lolium, Lema	Bioassay	May and Ash 1990
E. leucoxylon	Litter	Allocasuarina	Bioassay	Withers 1978
E. maculata	Litter	*Lemna*	Bioassay	May and Ash 1990
E. manifera	Litter	*Lemna*	Bioassay	May and Ash 1990
E. marginata	Dead leaves	Cynobacteria	chemistry	Wrigley and Cowan 1995
E. melliodora	Litter	*Lemna*	Bioassay	May and Ash 1990
E. microcarpa		Gonocarpus	pattern	Lange and Reynolds 1981
E. miniata		Various species	inference	Stocker 1969
E. ovata	Litter	Allocasuarina	Bioassay	Withers 1978
E. oblique	Leaves, litter	*Triticum, E. viminalis, Allocasuarina, Leptosermum*	Bioassay	del Moral *et al.* 1978
E. ovata	Litter	Allocasuarina	Bioassay	Withers 1978

5.1 Allelopathic Implications of *Eucalyptus* in Agro-ecosystems

Eucalyptus as an agroforestry component tree has been used for a long time. Recently a controversy among the planters has been arisen due to adverse effects on the adjoining crops; much of it came from neighboring countries (Dhillon *et al.* 1982, Kohli *et al.* 1990). Other controversies linked with the tree include lowering of water table, depletion of nutrients due to lesser leaf production in comparison to bole, delayed decomposition due to presence of volatile oils and waxy coating in the leaves and more soil sap requirement to meet the demands of fast growing and dividing cells (Kohli and Singh 1991). Keeping aside such controversies linked with the tree, the area under *Eucalyptus* plantation often houses poor vegetation. It is alleged that in spite of sufficient light intensity, nutrients or space to support vegetation, there is low biodiversity on its floor, for such an antiphytosocial property, allelopathy has been proposed to be the reason (Kohli 1990).

Plantation of *Eucalyptus* has created havoc to the adjoining crops to the extent that a space of 5-7 m adjoining of *Eucalyptus* has to be left vacant (Kohli and Singh 1991). Rabi and Kharif crops showed poor performance in terms of density, biomass, root and shoot length and economic yield in comparison to unsheltered areas (Kohli *et al.* 1990). Singh and Kohli (1992) have studied the impact of *Eucalyptus tereticornis* shelterbelts on some crops in India. They concluded that the poor performance of crops in the *Eucalyptus* shelterbelts area was related to an allelopathic effect of *Eucalyptus*.

5.2 *Eucalyptus* of Open-Forests and Woodlands

Prescott and Poper (1932) suggested that eucalypt oils might prevent seed germination. The presence of terpenes in eucalypt soils also has been reported by del Moral *et al.* (1978) and Lovett (1985). Many soils are water repellent, although this phenomenon is generally believed to be linked to fungal activity (Hubble *et al.* 1983). Prescott (1941) concluded that the usual paucity of seed germination is a reflection of harsh conditions and that germination occurs readily under favorable conditions.

Recently, the allelopathic potential of various plant parts of eucalypts including *E. globulus, E. maculata, E. rossii, E. rubida, E. mannifera, E. blakelyi, E. polyanthemis, E. melliodora, E. elata* and *E. radiata* have been studied in detail (May and Ash 1990). Generally, fresh foliar and root leachates prepared at concentrations simulating natural conditions showed no activity in bioassay with *Lolium* and *Lemna*. However, leaf litter leachates of *E. rubida* were inhibitory in bioassay, as were bark litter leachates of *E. globulus* and *E. rubida*. The most potent source of allelochemicals was stemflow, especially in *E. globulus* and this may be significant in explaining suppression zones near trees (Ashton and Willis 1982). Most of the extracts when artificially concentrated became strongly inhibitory and, again this may have significance in the field where successive wetting and evaporation can cause effective concentration of allelochemicals in the soil. May and Ash (1990) found differences in soil response to allelochemicals as eucalypt treated soil showed 24 percent germination of *Lolium* seed, whereas adjacent grassland soil showed only 5 percent germination. The authors concluded that while the production of allelochemicals may be greater in wetter climates, allelopathy may be of greater significance in drier climates where competition for moisture and the concentration of allelochemicals are more likely to cause suppression.

Costin (1954) reported that the peppermints, *Eucalyptus dives* and *E. radiata* of the Monaro region in New South Wales may exert an analogous influence on surrounding vegetation. It has often been reported that there is a ring of sparse vegetation beneath single eucalypt trees, which is particularly obvious in aerial photographs. Story (1967) suggested that such vegetational patterning beneath *Eucalyptus crebra, E. dawsonii, E. melliodora* and *E. moluccana* in the Hunter Valley region of New South Wales was not explainable by grazing or differences in soil moisture, and was possibly due to the action of associated microorganisms or exudates. Similar observations were made by Lange and Reynolds (1981) who reported the selective suppression of the herb *Gonocarpus eletius* beneath canopies of *Eucalyptus microcarpa*. Cremer (1990) reports that *E. camaldulensis* may exert a negative effect on the grazing yield of pasture in Western Australia.

5.3 Chemicals from Eucalypts

The presence of allelochemicals in *Eucalyptus* was reported by Baker and Smith (1920). Guenther (1950) reported that all species of *Eucalyptus* have foliar oil glands that are rich in essential oils principally terpenoids; typically 1 to 5% of the fresh weight is essential oil. The leaves also contain diverse phenolic compounds (Hillis 1967, Hillis and Brown

1984). Hillis (1967) isolated chemical compounds from *Eucalyptus* and identified nine compounds: titerpene esters named tereticornate A and B, ursolic acid lactone, ursolis acid, betulonic acid, undulatoside, sideroxylin, 8-demethylsideroxylin, and 1-triacontananol from the dry leaves of *Eucalyptus tereticornis*. The chemical constituents of leaf-oils and non-essential oils are shown in Table 5.2

Table 5.2 Chemicals obtained from *Eucalyptus*

The chemicals obtained from the *Eucalyptus* may be grouped into two classes:

a. Essential oils, and
b. Non-essential oil

Chemical constituents of *Eucalyptus camaldulensis* leaf oils		
Country	Chemical constituent of oil (%)	References
Bangladesh	1,8-cincole (39.7), citronellal (7.9), 4-terpinyl acetate (13.2), thujene (6.7) and 80 other constitutents	Manzoor-i-Khuda *et al.* 1987
India	α-pinene (4.89), β-pinene (10.29), terpin-1-ene-4-ol (10.50), α-terpincol (6.05), piperitone (7.87), 10 minor and 8 unidentified compounds	Dayal and Maheshwari 1985
India	α-pinene (16), β-pinene (16), α-terpinene (6.8), 1, 8-cineole (20.63), and p-cymene (24.57)	Singh and Sinha 1981
Egypt	b-phellandrene (8.94 and 4.09), p–cymene (24.01 and 10.61), cryptone (12.71 and 9.82) and spathulenol (14.43 and 13.14)	Fadel *et al.* 1999
Morocco	1,8-cincole (45.0 – 49.9), p-cymene (33.8 – 34.9), and 15 minor constituents	Zira and Benjilali 1991

Non-essential oil chemical constituents from *Eucalyptus camaldulensis*		
Bark	Oxalic acid	References
Leaf	Rutin	El-gammal and Mansour 1986
Leaf	Maslinic acid and Oleanolic acid	Movsumov and Aliev 1985
Leaf	Kaempferol 3-glucoside and glucuronide, quercetin 3-glucoside, 3-glucuronide, 3-rhamnoside, 3-rutinoside, 7glucoside and 7-glucuronide	Abd-Alla *et al.* 1980
Wood	Dimeric procyanidin	Dino and Luigi 1966

5.4 Allelopathy Experiments in the Institute of Forestry and Environmental Sciences

Considering the issues and debate of allelopathic effects of Eucalypts on associate crops, a series of experiments were carried out in the laboratory and nursery of the Institute of Forestry and Environmental Sciences, Chittagong University to assess and confirm the allelopathic effects of *Eucalyptus camaldulensis* on agricultural crops and forest crops. The series of experiments along with their outcomes are presented in the following sections. In all the experiments described hereafter, the effect was compared with control treatments. The data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT).

5.4.1 Allelopathic effects of *Eucalyptus* leaf-leachates in petridish

The study was in an aim to determine the allelopathic effect of leaf extracts of *Eucalyptus camaldulensis* on some agricultural crops. In the experiment, *E. camaldulensis* was the donor plant and the receptor species were Indian mustard (*Brassica juncea*), Cucumber (*Cucumis sativus*), Radish (*Raphanus sativus*), Falen (*Vigna unguiculata*) and Chickpea (*Cicer arietinum*). The aqueous extracts were prepared from dry and fresh leaves of 9 years old *E. camaldulensis* trees. 100 grams leaves were soaked in 500 ml of distill water and kept at room temperature. After 24 hour, the aqueous extract was filtered through the sieve and then extracts were diluted to make the concentration of 25%, 50% and 75% and stored for seed treatment experiments as follows:

T_0 = Seeds grown in distilled water only (Control)
T_1 = Seeds grown in Eucalypts leaf extracts of 25% concentration
T_2 = Seeds grown in Eucalypts leaf extracts of 50% concentration
T_3 = Seeds grown in Eucalypts leaf extracts of 75% concentration, and
T_4 = Seeds grown in Eucalypts leaf extracts of 100% concentration.

The germination test was carried out in sterile petridishes of 12 cm in size placing a Whatman No. 3 filter paper on petridishes. The extract of each concentration was added to each petridish of respective treatment daily in such an amount that just to wet the seeds. The control was treated with distilled water only. 20 seeds of each crop were placed in the petridish and each treatment was replicated 5 times. The experiment extended over a period of seven days to allow the last germination and the measurement of the shoot and root length (cm).

Germination (%): The germination percent of the 5-receptor plants are shown in Table 5.3. With the increase of concentration, the inhibitory effect was progressively increased. In most cases maximum inhibitory effect was found at T_4 treatment (100% conc.) and the minimum was found at T_1 treatment. Maximum inhibitory effect was found on *R. sativus* followed by *C. arietinum* in dry leaf extracts at T_4 treatment and the lowest was found in dry leaf extract on *C. sativus* at T_1 treatment. Though the germination percent of all test crops was reduced by the application of both dry and fresh leaf extract in comparison to control, but no significant effect was found on *C. sativus* (Table 5.3). It was observed that dry leaf extract reduced the germination of receptor crops to a greater extent than the fresh leaf extracts. The study confirms the findings of Al- Mousawi and Al-Naib (1975) who reported that three volatile inhibitors and five water soluble inhibitors were found in *Eucalyptus* leaves, which inhibited germination of seeds. The result also supports the findings of Rao and Reddy (1984) who found the inhibitory effect of *Eucalyptus* (hybrid) on germination of certain food crops in India.

Table 5.3 Germination percent of test crops to the aqueous extract of *E. camaldulensis*

Agricultural crops	Treatment								
		Dry leaf extracts				Fresh leaf extracts			
	T_0	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
C. arietinum	95 a*	45 b	35 b	23 bc	03 c	65 b	73 b	32 c	42 c
V. unguiculata	95 a	78 b	87 ab	83 ab	77 b	85 ab	83 ab	77 b	80 b
C. sativus	100 a	98 a	97 a	93 a	92 a	97 a	97 a	87 a	93 a
B. juncea	98 a	81 a	40 b	35 bc	18 c	85 a	58 b	27 c	22 c
R.. sativus	93 a	85 a	21 b	05 c	03 c	92 a	72 b	57 c	45 c

* Values in the columns followed by the same letter(s) are not significantly different (P≤0.05) according to the Duncan's Multiple Range test (DMRT).

Shoot elongation (cm): Significant shoot growth inhibition was found at T_4 and T_3 treatments followed by T_2 and T_1 treatments both for dry and fresh leaf extracts (Fig. 5.1). The dry leaf extracts at T_4 and T_3 was so severe that it completely inhibited (0%) the survivability of *B. juncea* and *R. sativus*. Maximum shoot elongation (20.1 cm) was found in *V. unguiculata* followed by *C. arietinum* (17.8 cm) both at control treatments. Among the survivors, the highest inhibitory effect was found on *C. arietinum* at T_4 treatment in dry leaf followed by the same crop at same treatment in fresh leaf and the lowest was found on *R. sativus* at T_1 treatment in fresh leaf. However, stimulating effect was also found on *C. sativus* at T_1 treatment and the lowest effect was found on *V. unguiculata* at the same treatment both in fresh leaf extracts. Maximum shoot elongation (20.9 cm) was observed in *V. unguiculata* at T_1 treatment for fresh leaf extracts followed by the same crop (20.1 cm) at control (Fig. 5.1).

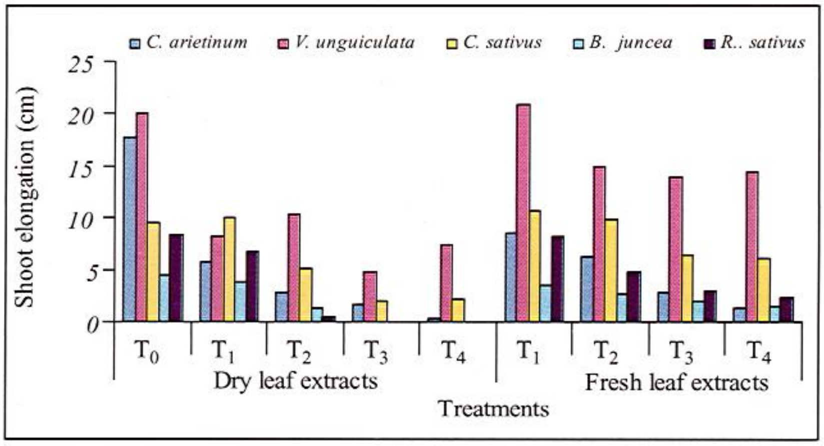


Figure 5.1 Shoot elongation (cm) of the receptor crops to the application of different concentrations of *E. camaldulensis* leaf extracts

Root elongation (cm): In comparison to control, all the treatments significantly reduced the root elongation except *V. unguiculata* in fresh leaf at T_1 treatment, where stimulatory effect was noticed. The inhibitory effect was progressively increased with the increase of concentrations (Fig. 5.2). Among the survivors, highest inhibitory effect was found on *R. sativus* at T_2 treatment followed by *B. juncea* at T_4 treatment both in fresh leaf extracts while the lowest was found on *V. unguiculata* at T_2 treatment. Maximum elongation (16.6 cm) of root was recorded for *R. sativus* followed by *C. arietinum* (15.5 cm) at control treatment.

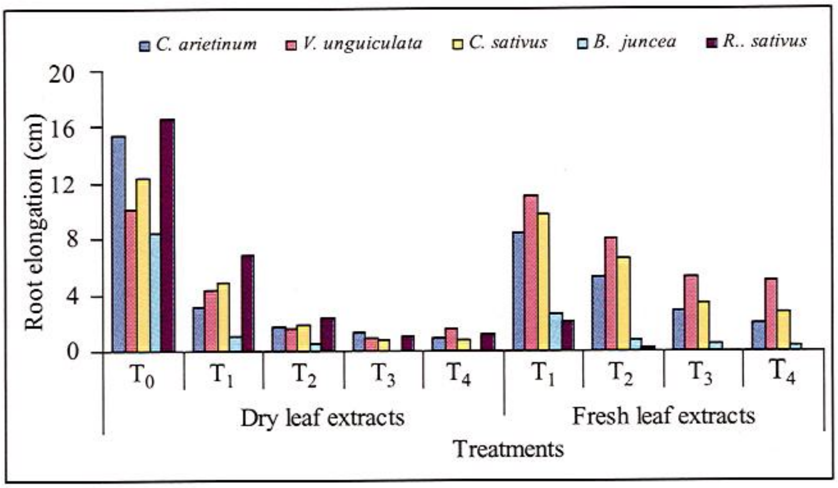


Figure 5.2 Root elongation (cm) of agricultural crops to the application of different concentrations of *E. camaldulensis* leaf extracts

Number of lateral root development: Considering the number of lateral root development, Ahmed *et al.* (2004) reported that the root development was significantly inhibited with the increased concentration of *Eucalyptus* leaf extracts. Significant effect was found at T_4 treatment followed by T_3, T_2 and T_1 treatments respectively and the effect was evenly increased from 25% concentration to onwards (Fig. 5.3). In most cases, T_1 and T_2 of fresh leaf showed stimulating effect. The highest stimulating effect was found on *B. juncea* at T_1 treatment and the lowest on *V. unguiculata* and *R. sativus* at T_2 treatment. *B. juncea* appeared as the most sensitive crop both to the exposure of dry and fresh leaf extracts. Among the survivors, highest inhibitory effect was found on *C. sativus* in dry leaf followed by *C. arietinum* in fresh leaf both at T_4 treatment and the lowest was found on *V. unguiculata* in fresh leaf at T_3 treatment (Fig. 5.3).

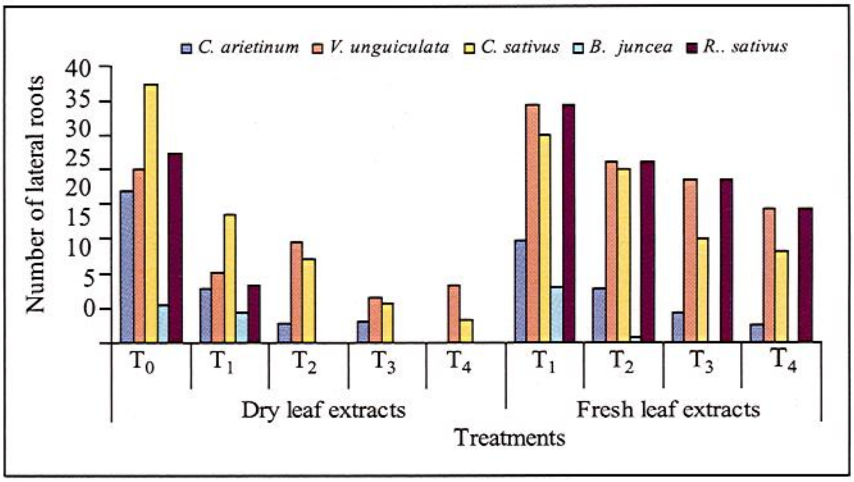


Figure 5.3 Number of lateral roots of agricultural crops to the application of different concentrations of *E. camaldulensis* leaf extracts

It was inferred from the study (Ahmed *et al.* 2004) that root and lateral root developments were affected more than germination and shoot elongation. These findings also correlated with the results of Chou and Waller (1980), Chou and Kou (1986), Zackrisson and Nilson (1992), Antonio *et al.* (1999) reported the root growth was more sensitive and responds more strongly to the increasing concentration of aqueous extracts. Among the 5-bioassay species, *B. juncea* and *C. arietinum* exhibited sensitive responses to the aqueous leaf extracts of *Eucalyptus camaldulensis* than the other test crops. Concentrations from 25% and onwards significantly reduce the germination, growth and development of root, shoot and lateral roots. The effect was more pronounced at higher concentrations, where the effect was so severe that T_3 and T_4 exhibited varying degree of necrosis and chlorosis, thin and grayish in color and in some cases mortality of seedlings. Many seedlings lost their ability to develop normally as a result of reduced radicle elongation and root necrosis. The detrimental effect of leaf extract of *Eucalyptus* on the test crops gives a clear example of how one species can significantly influence the development of others through the release of metabolic products. The aqueous extract of dry leaf severely suppresses the growth and development of test crops in comparison to aqueous extract of green leaf. This bioassay indicates that the dry leaves collected from the ground have the potential to release high amount of water soluble toxic compounds.

The study provides the evidence that *Eucalyptus camaldulensis* has allelopathic potential and some of the phytotoxins are water-soluble. Its inhibitory effect on agricultural crops is an evidence for allelopathy (Hossain *et al.* 2002). The conclusion is that allelopathy is caused by water soluble leachates from the dry and fresh leaves of *Eucalyptus camaldulensis* that have the potential to reduce the germination, suppress the growth and development of agricultural crops. However, while the potential of an allelopathic influence exist, it exists as a part of ecological complex. If we consider a compatible mixed cropping species combination for *Eucalyptus,* Cucumber (*Cucumis sativus*) and Falen (*Vigna unguiculata*) could be recommended for optimum production.

5.4.2 Allelopathic Effects of *Eucalyptus* Leaf, Stem and Roots to Agricultural Crops

Another experiment in Petridish was evaluated taking the samples of leaf, stem and roots from 10 years old *E. camaldulensis* trees. In the experiment, *E. camaldulensis* was the donor plant and the bioassay species were Mung bean (*Phaseolus mungo*), Chick pea (*Cicer arietinum*) and Pigeon pea (*Cajanus cajan*). Five and ten grams of the plant material were weighed, crushed and soaked in 100 ml of distilled water for 24 hrs, then homogenized and filtered using Whatman No. 3 filter paper. 5 and ten gram of soil sample collected from beneath the canopy of *E. camaldulensis* trees were soaked in 100 ml distilled water for 24 hrs and after shaking for 30 minutes were passed through Whatman No. 3 filter paper and then stored for treatment.

T_o = Seeds grown in distilled water only (Control)

T_1 = Seeds grown in leaf, stem and root extracts of 5% concentration and

T_2 = Seeds grown in leaf, stem and root extracts of 10% concentration.

Seeds were germinated using sterilized petridishes of 12 cm in size placing a Whatman No. 3 filter paper on each petridish. The extract of each concentration and each plant parts was added to each petridish of respective treatment in such an amount that can wet the seeds. The control was treated with distilled water only. 20 seeds of each agricultural crop were placed in the petridish and each treatment was replicated 5 times. The petridishes were set in the analytical laboratory of the Institute of Forestry and Environmental Sciences and the experiment extended over a period of seven days to allow the last seed germination. The seed was considered as germinated when the radicle emerged and the germination was recorded daily. The results were determined by counting the number of germinated seeds, number of lateral roots and measuring the length of primary root and main shoot on 7^{th} day of the experiment.

Germination (%): Germination response of test crop seeds to extract of different concentrations and control varied and did not follow any definite trend. However, germination percent decreased with the increase of concentrations. Among different parts of *E. camaldulensis*, leaf extract caused the most adverse effect followed by soil extract. Highest germination (100%) was found at control and soil extract of both concentrations in *C. cajan* while the lowest (77%) germination was found at 10% concentration in soil extract (Table 5.4).

Table 5.4 Germination percent of test crops to the aqueous extract of leaf, stem, root and soil of *E. camaldulensis* plantations

Plant parts/Soil	Treatments	*P. mungo*	*C. arietinum*	*C. cajan*
Leaf	T_0 (Control)	93 b*	87 d	100 a
	T_1 (5%)	97 a	63 b	93 c
	T_2 (10%)	90 c	63 f	93 c
Stem	T_0 (Control)	93 b	87 d	100 a
	T_1 (5%)	93 b	93 b	97 b
	T_2 (10%)	90 c	80 b	90 d
Root	T_0 (Control)	93 b	87 d	100 a
	T_1 (5%)	90 c	87 c	93 c
	T_2 (10%)	93 b	80 c	90 d
Soil (Eucalypt forest floor)	T_0 (Control)	93 b	87 d	100 a
	T_1 (5%)	97 a	97 a	100 a
	T_2 (10%)	77 d	90 c	90 d

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

Shoot growth (cm): Both the leaf and root extracts of *E. camaldulensis* significantly reducing shoot length of tested crops except for *P. mungo* which remained unaffected in expose to the extracts. An increase in extract concentration showed progressive increase in growth inhibition in most cases. Soil extracts had no significant inhibitory effect on all the test crops, on the contrary its 5 % concentration promoted the growth of tested seedlings (Table 5.5)

Table 5.5 Shoot elongation (cm) of test crops to the aqueous extract of leaf, stem, root and soil of *E. camaldulensis* in petridish

Plant parts/ or Soil	Treatments	*P. mungo*	*C. arietinum*	*C. cajan*
Leaf	T_0	25.8 a *	19.3 a	20.0 bc
	T_1 (5%)	25.5 a	17.6 ab	18.5 c
	T_2 (10%)	24.5 a	16.3 ab	15.8 d
Stem	T_0	25.8 a	19.3 a	20.0 bc
	T_1 (5%)	26.1 a	20.2 a	20.6 bc
	T_2 (10%)	24.8 a	19.9 a	18.6 c
Root	T_0	25.8 a	19.3 a	20.0 bc
	T_1 (5%)	25.8 a	19.8 a	21.8 ab
	T_2 (10%)	25.5 a	14.7 b	20.6 bc
Soil	T_0	25.8 a	19.3 a	20.0 bc
	T_1 (5%)	26.2 a	20.0 a	23.1 a
	T_2 (10%)	25.7 a	18.2 a	21.8 ab

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

Root elongation (cm): Negligible effect was induced on root growth of *C. cajan* by the donor plant while the other two crops of *P. mungo* and *C. arietinum* were significantly affected. Root and soil extract showed more inhibitory effect than that of stem and leaf extracts. Again, 10% concentrated extracts induced more effect than the extracts of 5 % concentration (Table 5.6).

Table 5.6 Root elongation (cm) of test crops to the aqueous extract of leaf, stem, root and soil of *Eucalyptus camaldulensis* in petridish

Plant parts/ Soil	Treatments	*P. mungo*	*C . arietinum*	*C. cajan*
Leaf	T_0 (Control)	10.6 ab *	18.2 ab	13.7 a
	T_1 (5%)	10.3 ab	18.2 ab	11.9 a
	T_2 (10%)	9.2 abc	17.6 ab	8.3 b
Stem	T_0 (Control)	10.6 ab	18.2 ab	13.7 a
	T_1 (5%)	11.2 a	21.6 a	12.6 a
	T_2 (10%)	10.4 ab	19.0 ab	10.7 ab
Root	T_0 (Control)	10.6 ab	18.2 ab	13.7 a
	T_1 (5%)	8.9 abc	19.3 ab	11.6 a
	T_2 (10%)	6.8 c	9.7 c	10.7 ab
Soil	T_0 (Control)	10.6 ab	18.2 ab	13.7 a
	T_1 (5%)	6.7 c	17.3 ab	13.0 a
	T_2 (10%)	7.5 bc	16.8 b	11.3 a

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

From this experiment, it may be concluded that for a mixture crop of Mung bean (*Phaseolus mungo*), Chick pea (*Cicer arietinum*) and Pigeon pea (*Cajanus cajan*), planting eucalyptus would not be harmful for a good agroforestry combination.

5.4.3 Allelopathic Effects of *Eucalyptus* Leaf-leachates in Crops Grown in Pot

Another pot experiment was conducted to evaluate the allelopathic potential of leaf-extracts of *Eucalyptus camaldulensis* on five common agricultural crops (Ahmed *et al.* 2007a) in the green house of the Institute of Forestry and Environmental Sciences of Chittagong University. The experiment was carried out in the pot of 8 cm x 5 cm size filled with soil collected from barren hills of Chittagong University campus. Each treatment was replicated 5 times and 5 seeds of receptor crops were sown in each pot. The test crops were Chick pea (*Cicer arietinum*), mustard (*Brassica juncea*), Falen (*Vigna unguiculata*), Cucumber (*Cucumis sativus*) and Radish (*Raphanus sativus*). The leaf extracts were prepared following the same as described in 5.4.1. The duration of the study was three weeks. The treatments were:

T_o = Seeds treated by distilled water only (Control)

T_1 = Seeds treated with 25% leaf extracts

T_2 = Seeds treated with 50% leaf extracts

T_3= Seeds treated with 75% leaf extracts, and

T_4= Seeds treated with 100% leaf extracts.

Germination of the crops was regularly recorded up to the last germination was noticed. Irrigation with extracts and distilled water were regularly applied twice a day for the respective treatments. All growth parameters like shoot and root length and leaf number were recorded.

Germination (%): Aqueous extracts of green leaves of *E. camaldulensis* had a strong significant inhibitory effect on germination of *C. arietinum, B. juncea* and *R. sativus* seeds especially at higher concentrations (Table 5.7).

Table 5.7 Germination (%) of different receptor crops to the application of leaf extracts of different concentrations of *E. camaldulensis* in pot

	Agricultural crops				
Treatments	*C. arietinum*	*B. juncea*	*V. unguiculata*	*C. cativus*	*R.sativus*
T_0 (0%)	96 a *	96 a	100 a	96 a	88 c
T_1 (25%)	96 a	100 a	100 a	96 a	96 a
T_2 (50%)	76 d	90 c	100 a	96 a	84 d
T_3 (75%)	92 b	40 d	100 a	88 b	92 b
T_4 (100%)	80 c	24 e	100 a	96 a	84 d

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

Uniform germination was observed in *V. unguiculata* at all treatments and *C. sativus* seeds were significantly inhibited only at 75% concentration (T_3). Among all the test crops, *B. juncea* was found most sensitive to the aqueous extracts of *E. camaldulensis,* while *V. unguiculata* and *C. sativus* were the most resistant species.

Shoot elongation (cm): Response of test crops expose to different concentrations of aqueous leaf extract of *E. camaldulensis* is shown in Table 5.8. The results revealed that shoot length of *C. arietinum* and *B. juncea* increased slightly up to 50% concentrations (T_2) in comparison to control, but significantly reduced at higher concentrations. T_1 treatment (25%) had the promotory effect on all the test crops.

Table 5.8 Shoot length (cm) of different receptor crops to the application of leaf extracts of different concentrations of *E. camaldulensis* in pot

Treatments	Agricultural crops				
	C. arietinum	*B. juncea*	*V. unguiculata*	*C. sativus*	*R. sativus*
T_0 (0%)	12.37ab *	2.4 a	21.48 a	8.45 c	8.16 ab
T_1 (25%)	14.1 a	3.87 a	22.35 a	11.08 b	8.83 ab
T_2 (50%)	14.01 a	3.39 a	22.97 a	13.37a	8.71 ab
T_3 (75%)	11.65 b	2.14 b	22.4 a	12.72 ab	9.37 a
T_4 (100%)	9.13 c	0.05 b	18.60 b	11.10 b	6.97 b

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

The effect was not similar in all cases. For example, in case of *V. unguiculata*, the effect remained non-significant even with the increase in extract concentrations up to 75%. *C. sativus* was found to have higher shoot length in all treatments than that of control.

Root length (cm): The effect of aqueous extracts of *E camaldulensis* leaf on primary root growth of tested seedlings showed that the root length of most crops in higher concentrations were shorter than that of control and lower concentrations. Exceptionally root length of *V. unguiculata* promoted at T_5 treatment (Fig. 5.4). However, fairly uniform root length with no significant difference was found in *C. sativus* and *R. sativus* at all treatments.

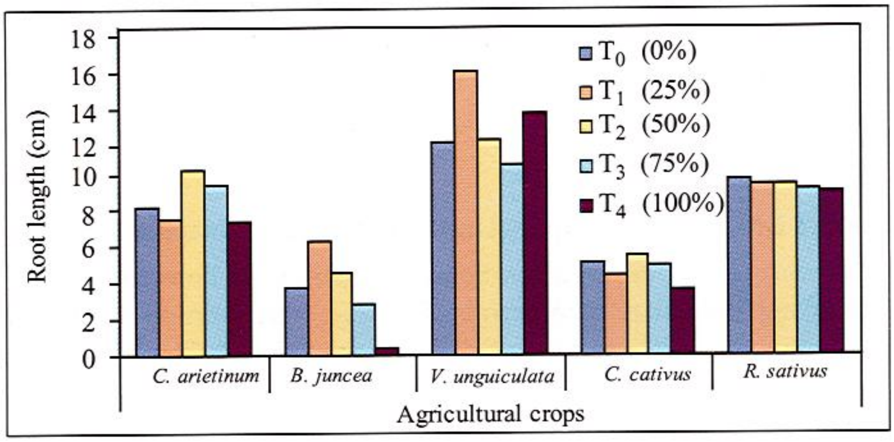


Figure 5.4 Root length (cm) of different receptor crops to the application of leaf extracts of *E. camaldulensis* in pot

Leaf number: Leaf number of tested agricultural crops in response to the application of different concentrations of *Eucalyptus camaldulensis* leaf extracts revealed that leaf number of tested seedlings was not significantly different among the treatments and the control (Fig. 5.5). However, leaf number was higher in seedlings treated with distilled water and extracts

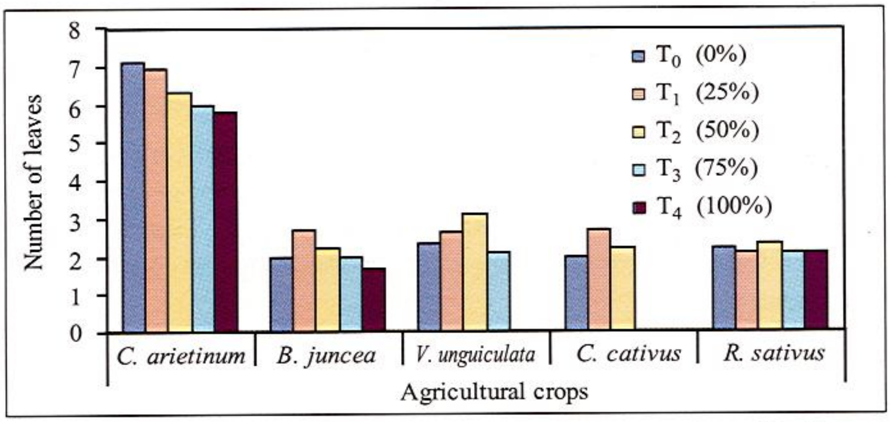


Figure 5.5 Average leaf number of different receptor crops to the application of leaf extracts of *E. camaldulensis* in pot

of lower concentrations. The study indicates the suppressive effect of *E. camaldulensis* on agricultural crops. Concentrations from 25% and onwards significantly reduce the germination, growth and development of root and shoot. The effect was more pronounced at higher concentrations, where the effect was so severe that T_3 and T_4 exhibited varying degree of necrosis and chlorosis, thin and grayish in color and some cases mortality of seedlings. Many seedlings lost their ability to develop normally as a result of reduced radicle elongation and root necrosis.

Similar effects of higher concentration of extracts were also observed in laboratory experiment (Ahmed *et al.* 2004). However, the effect was specific to growing condition as well as species. Laboratory experiment conducted in petridish showed severe effect and with the movement of study from laboratory to pot filled with soil, the effect appeared to be decreased. For example, the effect was very negligible or sometimes promotory on seedlings grown in pot when treated with low concentration of extracts and least affected crops were *V. unguiculata* and *C. sativus*.

5.4.4 Allelopathic Effects of *Eucalyptus* Leaf-litters in Germination Tray

Another experiment was set in the green house of Institute of Forestry and Environmental Sciences, Chittagong University with germination tray. Inner portion of the trays (9" x 9") were wrapped with soft clothes and then filled with treated soil. The bioassay species were Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*), Pigeon pea (*C. cajan*), Sil koroi (*Albizia procera*) and Ipil ipil (*Leucaena leucocephala*). The experiment lasted for one month in case of agricultural crops and two months for forest crops. The treatments used were:

T_0 = Seeds of receptor plants grown in tray with barren hill soil without mixing any leaf litter

T_1 = Seeds of receptor plants grown in tray mixed with litter of 1.046 gm

T_2 = Seeds of receptor plants grown in tray mixed with litter of 5.22 gm

T_3 = Seeds of receptor plants grown in tray mixed with litter of 10.46 gm

T_4 = Seeds of receptor plants grown in tray mixed with litter of 15.6 gm, and

T_5 = Seeds of receptor plants grown in tray mixed with litter of 20.96 gm.

Germination (%): Germination of test crop seeds showed significant variation in different treatments. In general, with the increased application of leaf-litter, germination rate of crops reduced (Table 5.9). Response of germination percentage at T_1 treatment was higher than that of control in all the crops, except *V. ungiuculata* where highest (100%) germination was found at T_4 treatment.

Table 5.9 Germination (%) of different receptor crops to the application of *E. camaldulensis* leaf-litter in germination tray

	Receptor crops				
Treatments	*C. arietinum*	*C. cajan*	*V. unguiculata*	*A procera*	*L. leucocephala*
T_0	98 b*	93 d	89 d	98 b	96 b
T_1	100 a	96 c	91 d	100 a	100 a
T_2	96 c	100 a	93 c	100 a	100 a
T_3	87 d	97 bc	98 b	95 c	100 a
T_4	98 b	98 b	100 a	94 c	82 c
T_5	96 c	71 e	98 b	73 d	78 d

* Values in the columns followed by the same letter(s) are not significantly different (P≤0.05) according to the Duncan's Multiple Range test (DMRT).

Shoot growth (cm): *Eucalyptus camaldulensis* leaf-litter reduced shoot length of all the crops except *C. arietinum* at T_1 treatment (Table 5.10), where stimulated shoot growth at 7.19% was recorded.

Table 5.10 Shoot length (cm) of different receptor crops to the application of *E. camaldulensis* leaf-litter in germination tray

	Receptor crops				
Treatments	*C. arietinum*	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	29.92ab*	27.21a	22.30a	22.33a	32.88a
T_1	32.07a	25.71b	21.25ab	21.00ab	32.25a
T_2	29.33b	24.11c	20.36b	17.83abc	20.75b
T_3	28.43b	23.00c	19.52c	19.67ab	20.42b
T_4	28.46b	23.95c	20.09c	16.17bc	22.00b
T_5	27.40b	22.95c	19.67c	14.17c	21.08b

* Values in the columns followed by the same letter(s) are not significantly different (P≤0.05) according to the Duncan's Multiple Range test (DMRT).

The results also revealed that the effect increased with the increase of leaf-litter application, but was not evenly increased. In comparison to the forest and agricultural crops, forest crops were affected severely than that of agricultural crops (Table 5.10).

Root length (cm): The root length of the crops was affected differently with applications of *Eucalyptus camaldulensis* leaf-litter. Both stimulatory and inhibitory effects were observed (Fig. 5.6) in the experiment.

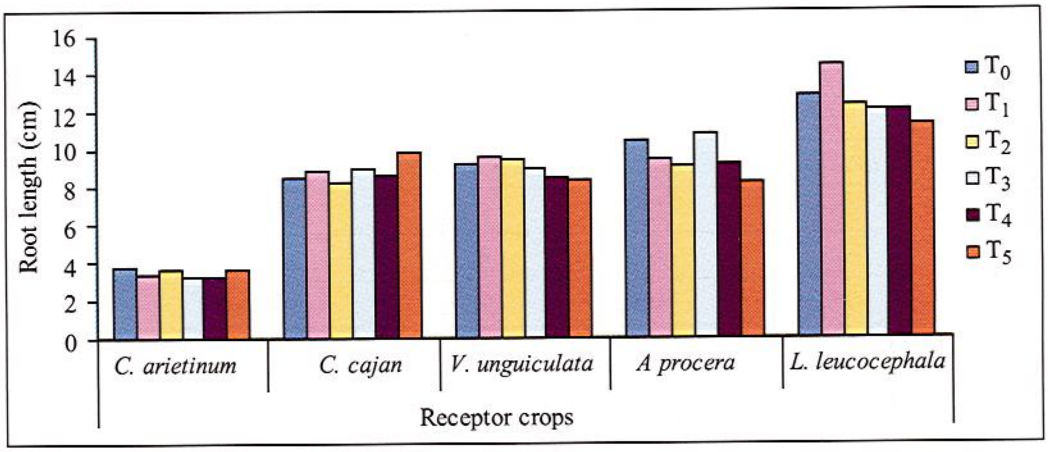


Figure 5.6 Root length (cm) of different receptor crops to the application of *E. camaldulensis* leaf-litter in different ratios

The results revealed that the effect was unevenly increased with the increase of leaf-litter. *C. arietinum* had the shorter root length in all treatments in comparison to control. On the contrary, *C. cajan* was stimulated with the increase of leaf-litter application. Highest (21.8%) inhibitory effect was found in *L. leucocephala* at T_5 treatment and lowest (2.8%) was found in *V. unguiculata* at T_3 treatment. Whereas, highest (16.7%) stimulatory effect was found in *C. cajan* at T_5 treatment and lowest (0.12%) in the same crop at T_4 treatment (Fig. 5.6).

Leaf Number: Number of leaves in all seedlings significantly reduced and it was decreased when concentration of leaf-litter increased except in *C. arietinum* (Fig. 5.7). T_1 treatments stimulated the leaf number of *V. unguiculata* and *A. procera* by 4.8% and 18.3% respectively. Highest (30.3%) reduction was found in *L. leucocephala* at T_5 treatment while lowest (1.4%) was in *C. arietinum* at T_1 treatment. In *C. arietinum* almost uniform leaf number was found for all treatments since there was no significant difference among the treatments. However, number of leaves was decreased with the increased application of leaf-litters (Fig. 5.7).

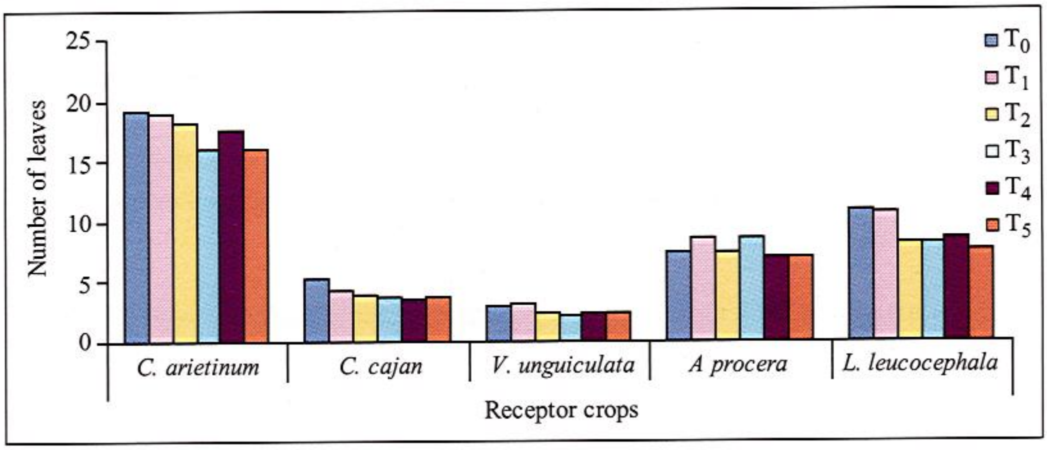


Figure 5.7 Number of leaves in different receptor crops to the application of *E. camaldulensis* leaf-litter in different ratios

The result of this experiment concludes that agricultural crops, e.g. Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*) and Pigeon pea (*Cajanus cajan*); forest crops Sil koroi (*Albizia procera*) and Ipil ipil (*Leucaena leucocephala*) could be compatible and potential combination with *Eucalyptus* in agroforestry or mixed cropping practices.

5.4.5 Allelopathic Effects of *Eucalyptus* Leaf-litters in Nursery Bed

The experiment was conducted in the nursery of Institute of Forestry and Environmental Sciences, Chittagong University, in a randomized block design. The receptor agricultural and forest crops selected were Falen (*Vigna unguiculata*), Chick pea (*Cicer arietinum*), Pigeon pea (*Cajanus cajan*), Sil koroi (*Albizia procera*) and Ipil ipil (*Leucocephala leucocephala*). The leaf-litter of *Eucalyptus* (*E. camaldulensis*) was collected from the floor of an 8 years old plantation. The litters were then air dried and grounded. The nursery bed was thoroughly prepared by adding 15 cm top soil from the barren hill. The bed was fairly leveled and all weeds and other debrises were cleared. Finally the grounded leaf-litter was mixed with soil uniformly in the following proportions-

T_0 = Seeds of receptor plants grown in bed with barren hill soil without mixing any litter (Control)
T_1 = Seeds of receptor plants grown in bed mixed with litter of 10gm m^{-2}
T_2 = Seeds of receptor plants grown in bed mixed with litter of 50gm m^{-2}
T_3 = Seeds of receptor plants grown in bed mixed with litter of 100gm m^{-2}
T_4 = Seeds of receptor plants grown in bed mixed with litter of 150gm m^{-2}, and
T_5 = Seeds of receptor plants grown in bed mixed with litter of 200gm m^{-2}

The litter was allowed to decompose for two months and occasionally the plots were watered. Then seeds of tested plants were sown. The agricultural crops were harvested after one and half month and forest crops after two and half months. The effect was compared with control where no leaf-litter was added.

Germination (%): Germination of tested agriculture and forest crops responded differently on different doses of leaf-litter. Seeds of all the crops were found to have highest germination rate at control except *L. leucocephala*. It had its highest (65%) germination percent at T_1 treatment (Table 5.11).

Table 5.11 Germination (%) of different receptor crops to the application of different proportion of *E. camaldulensis* leaf-litter in nursery bed

Treatments	Agricultural crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	48.0a*	58.0a	93.0a	73.0a	45.0b
T_1	43.0b	57.0a	92.0a	56.0c	65.0a
T_2	45.0b	58.0a	93.0a	70.0b	42.0c
T_3	43.0b	56.0a	83.0a	53.0d	25.0f
T_4	45.0b	56.0a	77.0a	52.0d	30.0e
T_5	45.0b	56.0a	79.0a	55.0c	38.0d

* Values in the columns followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to the Duncan's Multiple Range test (DMRT).

Apparently it was observed that with the increased application of leaf-litter, germination percent of the receptor crops were reduced. However, *V. ungiuculata* and *C. cajan* germinate in a fairly uniform rate with no significant variation among the treatments and the control. However, germination of forest crops was severely affected than that of agricultural crops, of which *L. leucocephala* was worst (Table-5.11).

Shoot length (cm): All treatments exhibit inhibitory effect on shoot growth of all the receptor crops, except *A. procera* where stimulatory effect was observed up to T_2 treatment (Fig. 5.8).

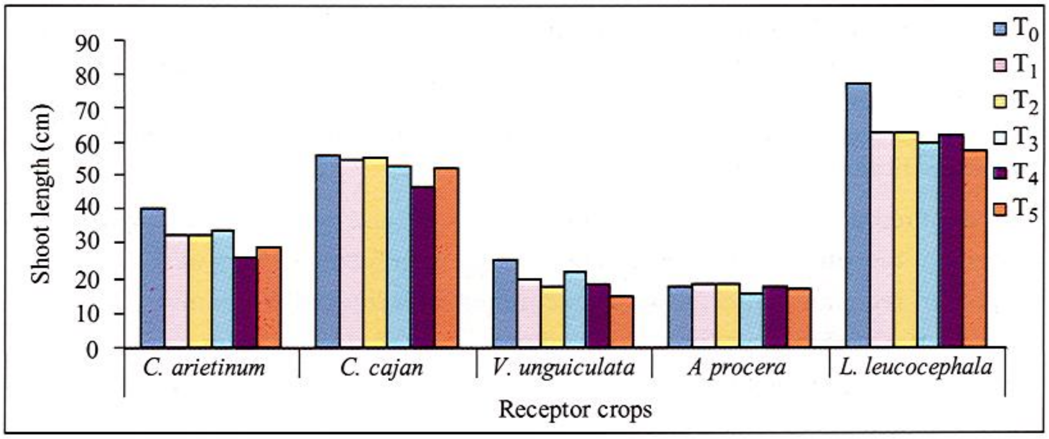


Figure 5.8 Shoot length (cm) of different receptor crops to the application of *E. camaldulensis* leaf-litter in nursery bed

Root length (cm): The roots of all the receptor crops at higher doses had shorter length than that of control (Fig. 5.9), but exceptionally the root length of *C. arietinum* responded unevenly, and stimulated at both T_1 and T_5 treatments.

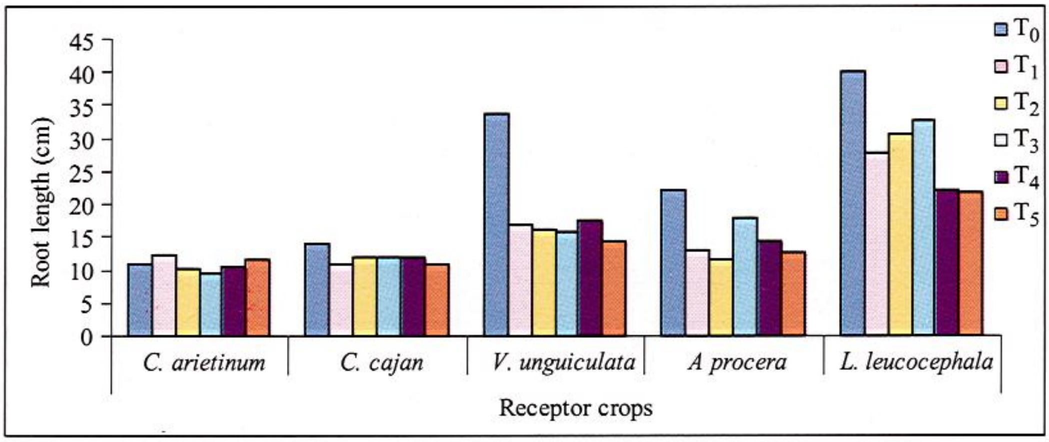


Figure 5.9 Root length (cm) of different receptor crops to the application of different proportion of *E. camaldulensis* leaf-litter in nursery bed

Significant reduction of root length (cm) in all other crops was found at T_5 treatment followed by the descending order of leaf-litter doses. Effects on root growth was more severe in comparison to the shoot growth, e.g., at T_5 treatment reduction of primary root development of *C. cajan*, *V. unguiculata, A. procera* and *L. leucocephala* was 22.5, 56.9, 42.1, and 45.6% respectively, while that of shoot growth of those crops was 8.5, 40.6, 2.8 and 25.2 percent respectively.

Leaf number: Number of leaves developed in the receptor crops differ significantly with the application of different doses of *E. camaldulensis* leaf-litters. Maximum effect was observed in T_5 treatment followed by T_3 and T_2 treatments respectively. However, T_1 treatment stimulated the leaf production of *C. arietinum*, *A. procera* and *L. leucocephala* (Fig. 5.10).

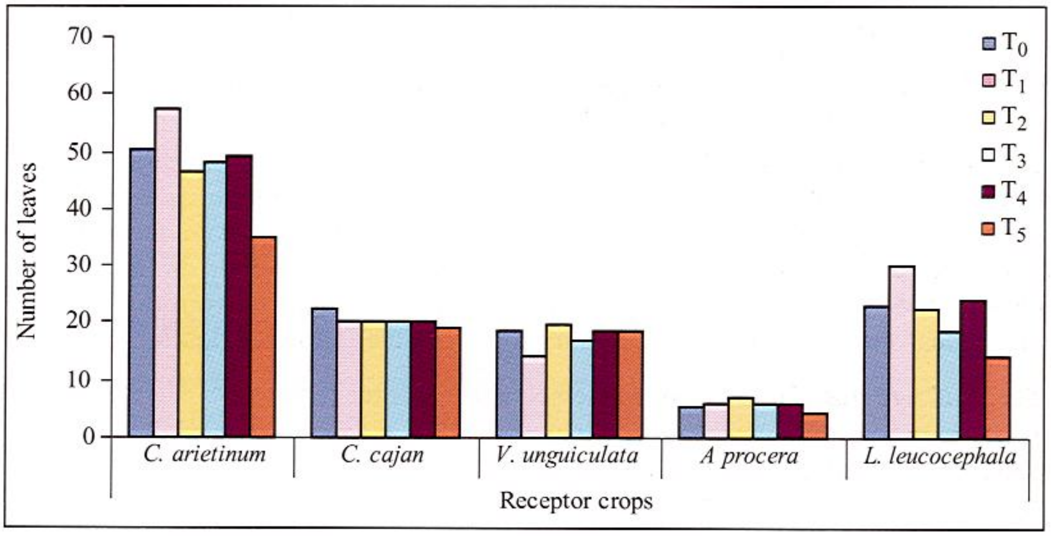


Figure 5.10 Number of leaves of different receptor crops to the application of *E. camaldulensis* leaf-litter in nursery bed

Number of nodules: *E. camaldulensis* leaf-litter had significant inhibitory effect on nodule formation of receptor crops. The inhibition was found pronounced with the increasing of leaf-litter percentage. However, different receptor crops responded differently in different treatments (Fig. 5.11). *V. unguiculata* and *A. procera* possessed the highest number of nodules in control treatment. Nodulation of *C. arietinum* and *C. cajan* was stimulated at T_1 and T_2 treatments and then followed a decreasing trend. In an average, maximum nodule (32.1) was recorded in *A. procera* at control, while minimum (0.3) was in *C. arietinum* at T_5 treatment (Fig. 5.11). Nodule number in *L. leucocephala* was more than any other tested seedlings but they were distributed in such a way that it was not possible to count, and hence discarded from the figure.

Root length (cm): Root length (cm) of receptor crops was not suppressed significantly for *A. procera* and *V. sinensis,* but it was significant for *G. sepium* and *A. esculentus* (Fig. 5.14). Root length increased in E_2 treatment for *A. procera* (+6.2%) and *V. sinensis* (+0.5%). But, the highest (-38.0%) inhibition was found in E_3 treatment followed by E_2 for *G. sepium*.

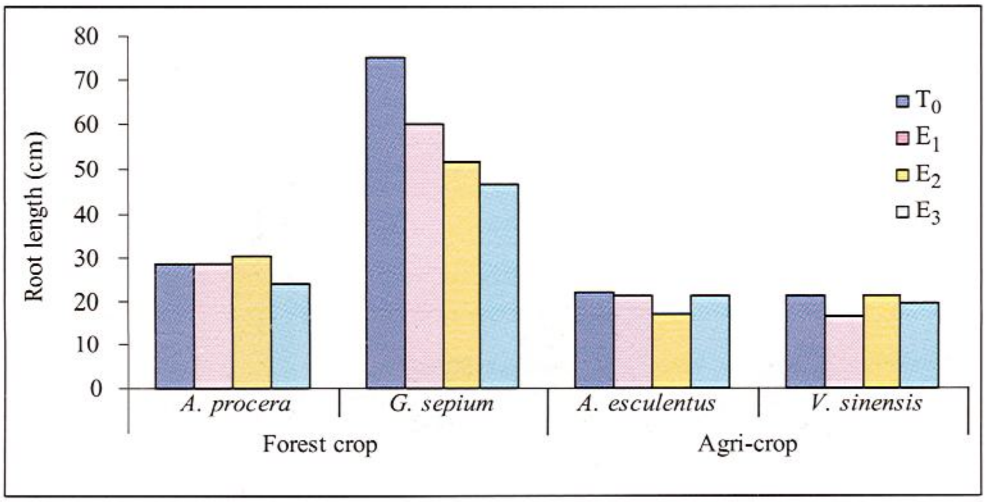


Figure 5.14 Root length (cm) of *A. procera, G. sepium, A. esculentus* and *V. sinensis* to the application of *E. camaldulensis* leaf-litter in nursery bed

Total above-ground plant mass (g/plant): The total above-ground plant mass (g/plant) was found significantly reduced for all the receptor crops except *A. esculentus* in comparison to control (T_0) treatment (Fig. 5.15). Significant reduction (-45.0%) was found in E_3 treatment for *A. procera*. In case of *V. sinensis,* total plant mass was found decreasing with increasing leaf litter doses.

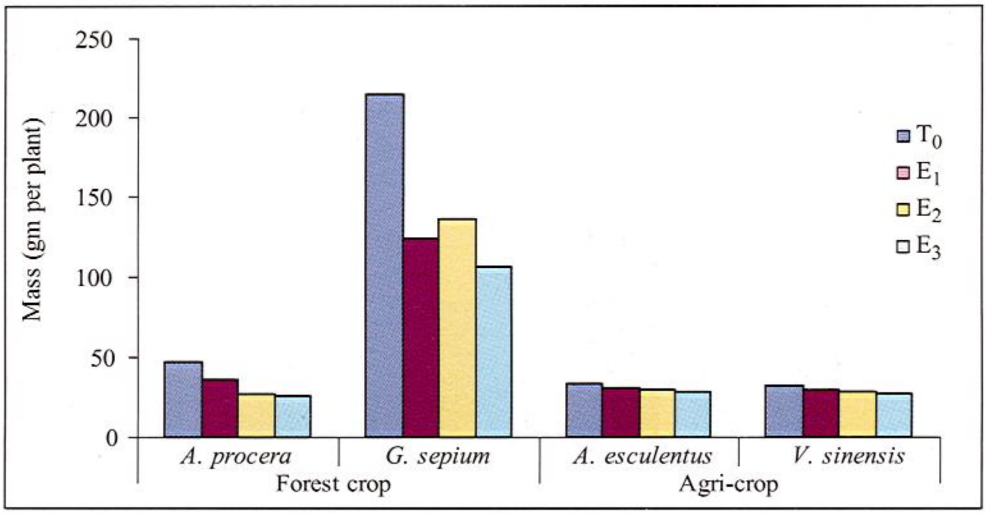


Figure 5.15 Total above-ground plant mass (g/plant) of *A. procera, G. sepium, A. esculentus* and *V. sinensis* to the application of *E. camaldulensis* leaf-litter in nursery bed

Number of gruits and weight (g) of fruits of agricultural crops: Production of total number of fruits for both the agri-crops significantly inhibited in higher doses in comparison to control (T_0) treatment (Table 5.13). Maximum inhibition (-25.1%) was found in *A. esculentus* for E_2 treatment followed by E_3 treatment and lowest (-6.7%) was also for *A. esculentus* in E_1 treatment. Similarly fruit production was decreased for *V. sinensis* with the increase of doses.

Accordingly, the total weight of fruits was also significantly reduced for both the receptor crops. Maximum reduction (-27.1%) was found for *A. esculentus* in E_3 treatment and lowest (-2.2%) for E_1 treatment for same crops (Table 5.13).

Table 5.13 Number and weight (g) of *A. esculentus* and *V. sinensis* fruits to the application of *E. camaldulensis* leaf-litter in nursery bed

Treatments	Total number of fruits		Total weight (g)	
	A. esculentus	*V. sinensis*	*A. esculentus*	*V. sinensis*
T_0	65 a *	86 a	878 a	935 a
E_1	61 ab	75 ab	858 a	862 ab
E_2	49 c	66 b	643 b	730 bc
E_3	50 bc	68 b	640 b	688 c

* Values in the columns followed by the same letter(s) are not significantly different ($P<0.05$) according to the Duncan's Multiple Range test (DMRT).

5.4.7 Effects of *Eucalyptsus* on Four Agricultural Crops in Field Plantations

The experimental site was selected at the *E. camaldulensis* plantations of Chittagong University campus. The hill soils of the selected area are well-drained, generally sandy loam to sandy clay loam, moderate acidic and poor fertile (Rashid 1991). The average annual rainfall of this area is about 2500-3000 mm, which mostly takes place between June and September. The seeds of four agricultural crops, e.g. mung bean (*Phaseolus mungo*), pigeon pea (*Cajanus cajan*), falen (*Vigna unguiculata*), and cowpea (*V. sinensis*) were sown in *E. camaldulensis* plantation sites in both plain and hilly land plantations sites. At the same time seeds of those crops were sown in the nursery in an aim to compare the germination and growth behavior of the crops. Seedlings were harvested after one and a half month of last germination. The treatments applied were as follows:

T_0= Seeds of receptor crops grown in nursery bed

T_1= Seeds of receptor crops grown in plain land eucalypt plantations

T_2 = Seeds of receptor crops grown in mid-slope eucalypt plantations, and

T_3= Seeds of receptor crops grown in lower slope eucalypt plantations.

Germination of the crops was regularly recorded up to the last germination. Watering and weeding were regularly done when required. No watering was done in case of field experiments. All growth parameter like shoot and root length, collar diameter, lateral roots, nodule number and size, leaf, leaflet number, root diameter etc. were recorded.

Laboratory experiments showed severe allelopathic effects and with the movement of study from laboratory to field condition, the effect appeared to be decreased, e.g. the effect was very negligible or sometimes promotory on seedling growth in plain land plantation of eucalyptus in comparison to control (nursery). Poor growth of the crops in hill plantation site might be due to some limiting factor of nutrients other than allelopathy. Though primary root development was significantly hindered in the plantation sites, lateral root expansion remained non significant and in some cases showed positive effect. However, better growth of some crops in mid-slope than that of lower slope may not be the nutrient factors, because nutrient status is generally better in bottom slope of the hill. This is probably due to leaching of some allelochemicals in the bottom slope as the experiment was conducted in the late rainy season. The detrimental effect of *Eucalyptus* on the test crops gives a clear example of how one species can significantly influence the development of others. This bioassay indicates that the dry leaves collected from the forest floor have the potential to release an amount of water-soluble toxic compounds. The conclusion is that allelopathy is caused by water-soluble leachates from the leaves of *Eucalyptus camaldulensis* may have the potential to reduce the germination, suppress the growth and development of agricultural and forest crops.

5.4.8 Comparative Allelopathic Effects of Eucalypts and Other Three Forest Trees on Germination and Initial Seedling Growth of *Leucaena leucocephala* in Nursery

The study was conducted at the Institute of Forestry and Environmental Sciences, Chittagong University, Bangladesh (Hossain *et al.* 2002). The natural forests of the area were cleared and presently all areas are planted with indigenous species like *Artocarpus chaplasha* and *Dipterocarpus turbinatus* and fast growing exotics such as *Acacia auriculiformis* and *Eucalyptus camaldulensis*. The treatments were consists of two factors: 4 tree species (*A. auriculiformis, A. chaplasha, D. turbinatus* and *E. camaldulensis*) and 4 mixtures of top-soil + leaf-litter (100:0, 90:10, 75:25 and 50:50) plus control making treatment combinations. Top 5 cm soil was collected from the plantation floor of 15 years old tree species separately and the soil collected from an adjacent scrub forest area was used as control. Leaf-litter was chopped into small pieces species wise and mixed with the topsoil of same species in a ratio of 100:0, 90:10, 75:25 and 50:50. The mixture was kept in the seed germination trays of 32 x 22 x 6 cm^3 in size. In each tray, 3.5 kg soil and 0.85 kg leaf-litter weight was used. Twenty seeds of *L. leucocephala* were sown in the mixtures of each germination tray. Before sowing, the seeds were soaked in water overnight. The treatments were replicated thrice in a randomized block design. Watering was done as required during the experiment. Care was taken to prevent the leaching of excess water from the germination tray. The result of the experiment is shown in Table 5.15.

Table 5.15 Effect of mixtures of topsoil + leaf-litter of four tree species on germination (7 days after sowing) and seedling growth (90 days after sowing) of *L. leucocephala*

Tree species (soil + leaf-litter ratio)	Germination %	Height (cm)	plant mass (g/plant)	Collar diameter (mm)	Root length (cm)	Nodule (no./plant)
Control (Adjacent to scrub area)	96a***	9.1g	1.28fg	2.12hi	14.20defg	10.6ab
Acacia auriculiformis						
A_0 (100* + 0**)	93a	18.56de	5.97d	3.50bc	21.82c	4.9de
A_1 (90 + 10)	96a	24.12c	8.97c	3.82b	21.82c	4.9de
A_2 (75 + 25)	89a	28.54a	14.20b	4.20a	33.73a	0.6g
A_3 (50 + 50)	87a	24.66b	18.28a	5.10a	28.30b	2.4f
Artocarpus chaplasha						
C_0 (100 + 0)	93a	11.03fg	1.70fg	2.36ghi	14.70defg	6.9bcd
C_1 (90 + 10)	91a	12.46fg	1.72fg	2.12hi	15.64def	7.1bcd
C_2 (75 + 25)	93a	14.24ef	2.34efg	2.74fg	15.56def	6.3cde
C_3 (50 + 50)	93a	18.9de	4.09dc	3.39cd	21.23c	2.7ef
Dipterocarpus turbinatus						
D_0 (100 + 0)	87a	12.0fg	2.02efg	2.56fgh	16.63de	11.8a
D_1 (90 + 10)	100a	13.37fg	2.01efg	2.82ef	15.13defg	9.3abc
D_2 (75 + 25)	91a	21.39cd	3.64ef	3.11de	16.60de	3.0ef
D_3 (50 + 50)	91a	22.0cd	4.12de	3.11de	17.70cd	9.1abc
Eucalyptus camaldulensis						
E_0 (100 + 0)	89a	9.26fg	1.23g	2.13hi	11.96efg	0g
E_1 (90 + 10)	98a	9.34fg	10.9g	1.94ij	10.78g	0g
E_2 (75 + 25)	87a	8.42g	1.03g	1.94ij	12.20fg	0g
E_3 (50 + 50)	42b	8.32g	0.89g	1.66j	11.76fg	0g

(*- Forest top soil, **- Leaf-litter, ***- different letter(s) in a column indicate values significantly different at 0.01 level as determined by Duncan's Multiple Range Test)

Maximum germination occurred in for the *D. turbinatus* soil + leaf-litter mixture (90:10), but the differences were not significant for other treatments except E_3 treatment (Table 5.15).The lowest germination (42%) was found in *E. camaldulensis* soil + litter (50:50) mixture and it showed 44% inhibition of germination in comparison to control treatment. Except eucalypts mixtures, all mixtures of forest top soil + leaf-litters produced taller seedlings in comparison to control treatment. Eucalypt mixtures produced the poorest seedlings even than control. Though the leaf-litter of *A. auriculiformis, A. chaplasha* and *D. turbinatus* increased the height, plant mass, collar diameter and root length of ipil-ipil seedlings, but the *Eucalyptus* litters decreased all the parameters even, in comparison to control treatment. These findings indicate that litter-fall returned a substantial amount of nutrients to the forest floor and increases the soil fertility, whereas eucalypt litters are not increasing the fertility but posing some allelopathic effects.

All the above studies provide the evidence that *Eucalyptus camaldulensis* has allelopathic potential and some of the phytotoxins are water-soluble. Its inhibitory effect on agricultural crops is an evidence for allelopathy (Hossain *et al.* 2002, Ahmed *et al.* 2004, Ahmed *et al.* 2008). The conclusion is that allelopathy is caused by water-soluble leachates from the leaves of *Eucalyptus camaldulensis* that have the potential to reduce the germination, suppress the growth and development of agricultural crops to certain extents. Allegation exist that litters of *Eucalyptus* spp. exert allelopathic effects on the site (Ahmed *et al.* 1982, Singh and Bawa 1982, Rao and Reddy 1984). There have been a number of studies on allelopathy in *Eucalyptus*, particularly in India where planting of *Eucalyptus* is greatly controversial (Willis 1991). The subject of allelopathy in Bangladesh is still in a primary stage. Though the inhibitory effect of *Eucalyptus* is a concern to environmentalists in Bangladesh, very few research works carried out in this regard (Uddin *et al.* 2000, Hossain *et al.* 2002, Ahmed *et al.* 2008). The need for assessing allelopathic compatibility of crops with trees was stressed by several authors (Gaba 1987, King 1979) before including them in agroforestry system. Finally, these experiments once again conclude that combination of selected agri-crops with *Eucalyptus* could be recommended for optimum production instead of completely keeping *Eucalyptus* away from further planting.

Chapter 6

Social Implications of Planting Eucalypts in Bangladesh

The future of eucalypts in Bangladesh depends on the acceptability of the species in the society among different groups of people. To indicate the degree of acceptability, it would be relevant to understand how people react with participatory forestry practices especially in woodlot and agroforestry plantations, where eucalypts are a major component of the systems. People's participation, so far, is encouraging in such plantation activity. In a social study, it was found that on the average woodlot and agroforestry plantations were about one hectare per family, and people's participation was increasing day by day. In Northern Bangladesh, agroforestry practice already got momentum with active participation of mass people (Bhuiyan 1995, Hassan 1995, Ahmed 2001).

Social surveys can be an indicator of social acceptance of eucalypts. Chowdhury (1993) interviewed people living in and near the forest and plantation areas to understand their preference in selecting species. Among the interviewee, 80% favored short rotation species, 15% favored combination of short and medium rotation species, whereas less than 2% respondents favored long rotation species; the rest did not have any choice or they did not understand about the choice (Fig. 6.1). However, none mentioned fuelwood as the first priority; but the majority advocated for cash returns. It was opined that the majority preferred *E. camaldulensis* and *A. auriculiformis* for immediate returns from plantations. These species are significantly contributing to the forest products in the society **(Figs. 83, 84, 85, 86, 87 and 88).**

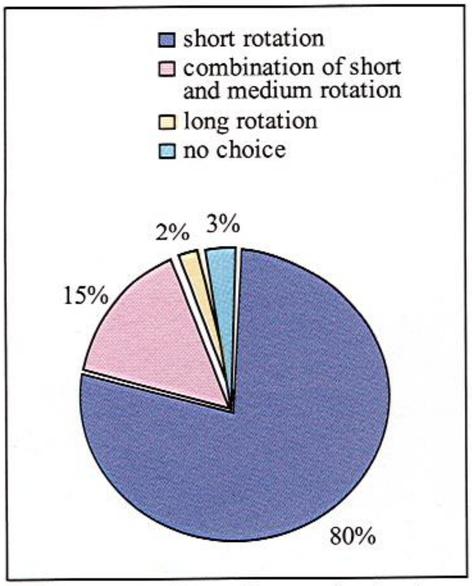


Figure 6.1 Peoples preference for planting different rotation species

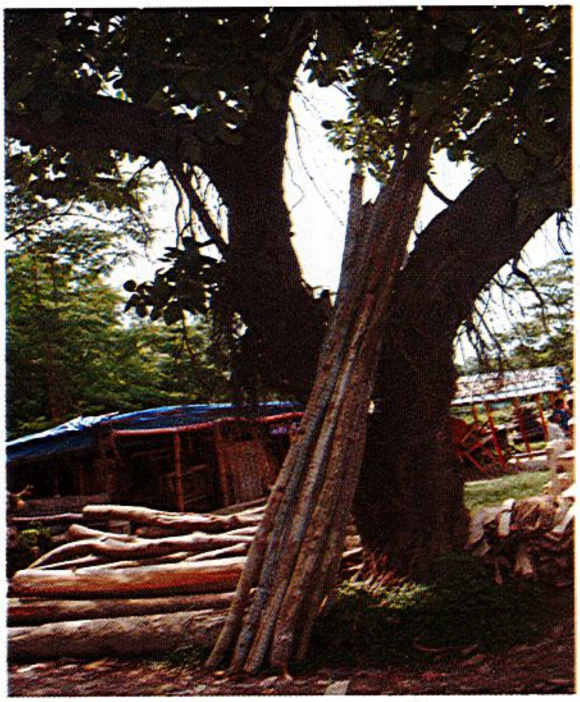


Figure 83. Small *Eucalyptus* posts in the local market

Figure 84. Eucalypts and *Acacia* are contributing in supplying forest produces in the rural areas

The Swiss Agency for Development and Cooperation (SDC) has been sponsoring research from 1986 on tree growing in the 'khet' (crop land). The research findings show that the farmers favor *E. camaldulensis* (unpublished data). In the D & D (Diagnosis and Design) survey, conducted by Bangladesh Agricultural Research Institute (BARI), BRAC and ICRAF in 1991, it was reported that the tendency was to give lowest priority to trees in terms of resource allocation and management inputs, as farmers have little knowledge of production potential and management of trees. However, if they are motivated and provided with technology, they would prefer eucalypts as their first priority species in agroforestry because of its better crown architecture supportive or suitable to their agricultural crops.

Figure 85. *Eucalyptus* poles and posts for sale

Figure 86. *Eucalyptus* sawn timbers in the local market

Figure 87. Furniture made of *Eucalyptus* wood (Courtesy: BFRI)

Figure 88. *Eucalyptus* also used for boat building in Kutubdia

A third approach could be users' preference. With the increase in alternative uses of eucalypt, its acceptability will increase. For instance, cottage industry where about 75% of total industrial labour forces are employed (Chowdhury 1993), depends on local timber species, bamboo, canes, and murta. Exotic species like *Acacia* and eucalypts are yet to be exploited in this sector. Though eucalypt can be used in many secondary timber based industries as pulp, veneer, hardboard, particle board, matches and furniture, it is not used for such purposes in Bangladesh. If the uses of eucalypt are fully explored, and management techniques to increase production rate per unit land area are adopted, their acceptability will increase further in the society.

Agroforestry is a form of integrated land use systems, which consists of woody perennial favorably mixed with annual crops and other production enterprises, like animals to derive various benefits and utilities from the same piece of land (Bhuiya *et al.* 2001). The practice of agroforestry is an age-old practice in the traditional farming systems in the tropics including Bangladesh, although it is newer as a discipline (Karim and Savil 1991). In Bangladesh, trees are planted around homesteads as a part of whole farm systems to produce food, fodder, fuel, timber and organic matter and supports other functions like wind break and shade (Gujral 1990). The homestead forestry provides nutrition through the production of different fruits and vegetables. Agroforestry practices in both encroached forestland and homestead areas have, therefore, emerged as a pressing national land use, demanding for tree production along with crop and other areas (Bhuiya *et al.* 2001). In the present context of Bangladesh, agroforestry practices are appropriate for long-term benefits. A unique combination of different species of fruits, timber and biomass yielding trees can generate high amount of earnings for the farmers of Bangladesh (Abedin *et al.* 1990, Chowdhury and Sattar 1993).

In an agroforestry system there are agronomic, ecological and economical interactions among the various components. Homestead agroforestry plays a very important role in Bangladesh economy. Income from home gardens ranges from 26 to 47% of the total family expenses (Millat-e-Mostafa 1997). Agroforestry significantly contributes towards carbon balance. The role of soils in carbon storage has been somewhat overshadowed by tree-planting efforts. While planting tree is important to increase carbon storage, conserving soils is also essential. Soils are the largest non-fossil land based organic carbon reservoir. In both tropical and sub-tropical countries, *Eucalyptus* as an agroforestry component tree has been used for a long time. Not only in Bangladesh, eucalypts are popularly grown in India (**Figs. 89 and 90**) and in China (**Figs. 91 and 92)** also.

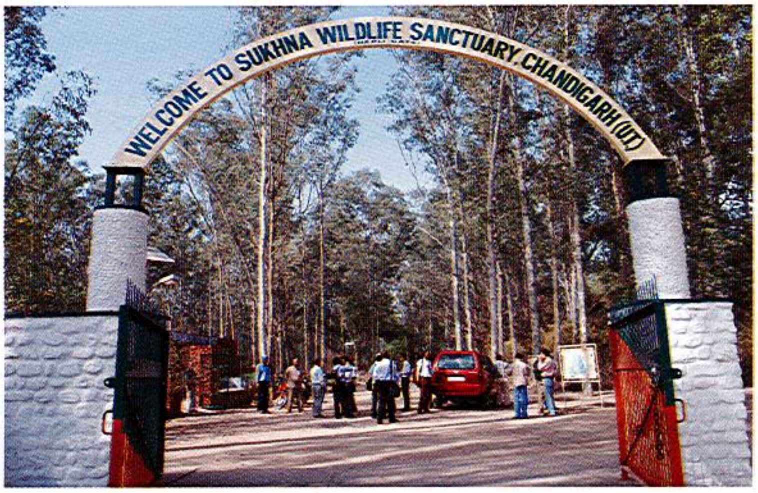


Figure 89. Eucalypts also found in Wildlife Sanctuary in India

Figure 90. Eucalypts supports ground vegetation in Wildlife Sanctuary in India

Figure 91. Eucalypts also a preferred plantation species in China

Figure 92. Wood chips are made from Eucalypts in China

6.1 People's Attitude about Eucalypts planting in Sitakunda Area (2003-2007)

It is observed that *Eucalyptus* species have been extensively planting in the homestead, fallow land and agricultural fields of Sitakunda upazilla, Chittagong (Ahmed *et al*. 2007b). Sitakunda has been selected purposively to check the social acceptance and people's perception regarding *Eucalyptus* as a plantation species.

A total of thirty respondents were selected in the study area, ten from each category of-

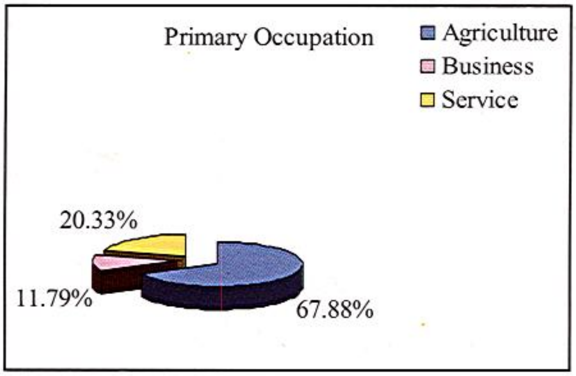
a) Farmers practicing agroforestry in agricultural lands,

b) Farmers having monoplantation of *Eucalyptus* species in homestead fallow land, and

c) Farmers having homestead mixed plantations with *Eucalyptus* species in homestead fallow land.

A detailed socio-economic survey relating to family size, educational status of family head, annual income, occupation and their land holdings was carried out using a semi-structured questionnaire. Detailed information regarding the agroforestry practices was then explored using semi-structured questionnaire. Agriculture was the major occupation of the selected respondents (67.9%) followed by employment in various organizations (20.3%) and business (11.8%) (Fig. 6.2).

Only 45.7% of the respondents had secondary occupations comprising agriculture (17.6%), employment in various organizations (4.8%) and business (23.2 %). Among 30 respondents, 58% collected *Eucalyptus* seedlings from private nurseries and remaining 42 % from local market. Forest department did not raise any *Eucalyptus* seedlings due to Government restrictions.



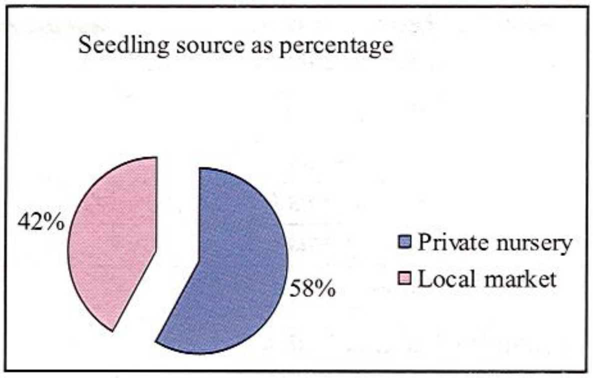


Figure 6.2 Primary occupation of respondents and sources of eucalypt seedlings

Mono-plantation of *Eucalyptus*: Mono-plantations of *Eucalyptus* were raised on the homestead fallow lands. 100 % of the respondents informed that it was the abandoned part of the homestead where stagnant water exists for long time. But, the site was not harmful for *Eucalyptus* trees as the species are growing well. During the survey, some mono plantations were also seen in the agricultural lands.

Homestead mixed plantations including eucalypts: *Eucalyptus* was seen randomly growing with other species in home gardens in the study area. The result showed that 67 % of the respondents planted eucalypts in the border of the homesteads, while 18% planted in mix with other species in the bunds of the ponds and remaining 12 % of the respondents planted it in a mixture with other species (Fig. 6.3).

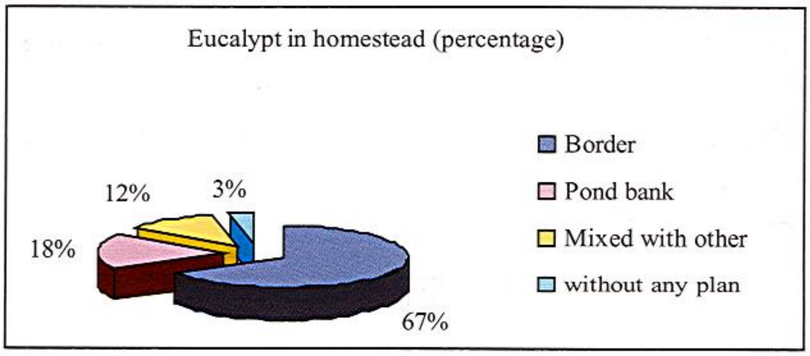


Figure 6.3 Percentage of eucalypts grown in homesteads

Effect of *Eucalyptus* on associated crops: *Eucalyptus* was raised as an agroforestry component in agricultural field and other fallow lands with an aim to get more economic return. The main agricultural crops grown were bean and rice. Most farmers reported the depressing effect of *Eucalyptus* on rice yield. However, there was variation of its effect with ages as they observed. Production of paddy progressively declined with the increasing age of *Eucalyptus* plantations. Plants of above 10-year old had the most adverse effect on the yield as it caused almost 15% reduction of yield on an average, while trees of 7-10 years old age reduces about 12% and 5-7 years trees reduces 8% yield (Table 6.1). The farmers also opined that this is also applicable with other tree species; even the situation is severe with *Albizia saman* (rain tree) because of its wide spreading canopy.

that the elongated crowns and vertical roots of *Eucalyptus* do not noticeably reduce crop yields. Farmers also think that they can use or sell the produce from the trees remarkably. From the findings, it can be considered that *Eucalyptus* has a promising prospect in Sitakunda Upazilla. Local people are also interested to plant it to meet their immediate demand within a short period. During the survey, some farmers were enthusiastic to raise mono-plantations of *Eucalyptus* even in their agricultural lands. If they get a good return, it may be so happen that many other farmers will take *Eucalyptus* plantation as a new initiative in the area. The most important aspect is that, whether farmers raise mono-plantation, mixed plantation or agroforestry practices, in each case the ultimate goal is the quick return from the plantations. They expect that not only border planting but also strip plantation and block plantation may also be practiced in the near future. Though people are practicing all of these and they have special eagerness in agroforestry.

6.2. Eucalypts in Homestead and Marginal Lands of Mirsarai and Sitakunda Upazila (2009-2010)

The study was principally aimed to reflect the present status of *Eucalyptus* and its cultivation in the rural landscape of Sitakunda and Mirsarai upazila of Chittagong district. However, the socio- economic condition and the impact of cultivation, yield of timber in respect to age and site, marketing pattern, hindrances and opportunities were also assessed. Data were collected from 50 respondents in the study area categorizing them into tree cultivator, middleman and nursery owner. A semi-structured questionnaire was used to interview them. 50 experimental plots were taken at five sites, e.g., homestead, pond bank, roadside, fallow land and in crop field boundary.

***Eucalyptus* at homesteads:** Growth performance of *Eucalyptus* plantations in homesteads of 3-16 years old is shown in Table 6.2. *Eucalyptus* is getting preferences in new homesteads in comparison to old ones. Maximum volume (4.81 $m^{3)}$ per households was found in 16 year old plantations of 80 year old homesteads. Highest volume per hectare (120.27 $m^{3)}$ was found in 16 year old plantations (Table 6.2).

Table 6.2 Growth performance of *Eucalyptus* plantation in homesteads

Homestead age (year)	Area of the house hold (m^2)	No. of non-*Eucalyptus* species	No. of *Eucalyptus*	Age (year)	Height (m)	*Eucalyptus* DBH (cm)	species Volume /house hold (m^3)	Volume /ha (m^3)	MAI $m^3h^{-1}yr^{-1}$
80	480	27	-	-	-	-	-	-	-
3	203	5	14	3	4.20	14.98	0.74	18.51	6
20	320	17	14	5	5.50	16.22	1.06	26.52	5
20	3200	45	67	6	6.61	18.45	1.47	36.84	6
20	435	12	16	8	7.00	20.18	1.64	41.05	5
16	1400	20	54	9	7.40	22.06	1.69	42.43	5
70	7206	35	7	10	8.15	25.37	2.47	61.80	6
25	411	9	26	12	8.70	27.15	2.68	67.17	6
70	1365	21	3	13	8.90	30.29	3.20	80.15	6
80	1800	53	4	16	9.06	36.78	4.81	120.27	8

Highest mean annual increment (8.00 m^3 ha^{-1} yr^{-1}) was found in 8 year old eucalypt plantations. There are some variability on overall growth performance of *Eucalyptus* at homestead plantations. This may be due to the site quality and density of the trees. Some new household plantations showed promising performance in comparison to old plantations because newly established household soil is more loose and fertile in comparison to old households.

***Eucalyptus* plantation at pond bank:** Growth performance of *Eucalyptus* plantation at pond bank from 3 to 10 year old age is shown in Table 6.3. The plot size was 10 m × 2 m. Highest volume (179.15 m^3) per hectare was found in 5 year old plantations. Lowest volume per hectare (33.44 m^3) was found in 4 year old plantations. Highest mean annual increment (11.99 m^3 ha^{-1} yr^{-1}) reported from a 5 year old plantation. However, the growth data is from small plots and edge effects are not measured. Lowest mean annual increment (7.69 m^3 ha^{-1} yr^{-1}) was found in 4 year old plantation (Table 6.3).

Table 6.3 Growth performance of *Eucalyptus* plantation at pond bank

Spacing (m × m)	Stock ha^{-1} (number)	Age (year)	Height (m)	DBH (cm)	Survival (%)	Volume ha^{-1} (m^3)	MAI $m^3h^{-1}yr^{-1}$
1.70 × 1.70	2941	3	5.28	8.56	85	70.03	9.92
2.70 × 2.70	1097	4	5.79	13.6	80	33.44	7.69
1.73 × 1.73	2539	5	8.07	10.57	76	122.50	11.99
1.47 × 1.47	3424	5	7.52	9.15	74	179.15	11.29
3.07 × 3.07	806	6	8.19	18.22	76	53.60	9.57
2.46 × 2.46	1074	6	7.48	17.46	65	99.10	10.69
2.28 × 2.28	1154	7	7.91	16.97	60	129.08	9.84
2.11 × 2.11	1550	8	8.02	16.98	69	172.37	11.73
3.16 × 3.16	621	9	9.25	22.91	62	92.95	8.77
3.21 × 3.21	631	10	9.57	24.54	65	100.92	9.52

Eucalyptus plantation at crop field boundary: Growth performance of 3 to 9 year old Eucalyptus plantation at crop field boundary is shown in (Table 6.4).

Table 6.4 Growth performance of *Eucalyptus* plantations at crop field boundary

Spacing (m)	Stock ha^{-1} (number)	Age (year)	Height (m)	DBH(cm)	Survival%	Volume ha^{-1} (m^3)	MAI $m^3h^{-1}yr^{-1}$
1.85 × 1.85	2776	3	6.54	8.32	95	32.88	10.96
2.40 × 2.40	1493	3	7.44	9.54	86	26.47	8.82
1.66 × 1.66	3157	5	5.63	10.15	87	47.95	9.59
1.74 × 1.47	2774	5	5.98	10.76	84	50.33	10.07
1.83 × 1.83	2240	6	5.35	13.53	75	57.48	9.58
1.16 × 1.16	5202	6	6.54	8.98	70	71.79	11.96
1.81 × 1.81	2045	7	6.89	13.98	67	72.10	10.30
1.77 × 1.77	2234	7	7.25	13.63	70	78.80	11.26
1.63 × 1.63	2446	8	6.26	15.34	65	94.36	11.79
1.82 × 1.82	1660	9	7.64	17.62	55	127.46	11.45

The plot size was 10 m × 0.5 m and highest volume (127.46 m^3) per hectare was found in 9 year old plantations. Lowest volume per hectare (26.47 m^3) was found in 3 year old plantations. The reason could be the density of trees inside the plot, site quality and the results may not be projected for large scale plantations.

Case study 1: *Eucalyptus* in Chittagong

The authors have some studies regarding the farmers and individuals interest in planting *Eucalyptus* inspite of the ban on further *Eucalyptus* plantings in Bangladesh. The studies were performed in Sirajgonj, Sitakunda and Mirsarai of Chittagong because most of the homesteads and fallow lands of these areas are planted with eucalypts. Eucalypt log and sawn timbers are also available in the local markets of these areas.

The farmers name is Mr. Mostafizur Rahman of about 70 year old. He is living in Muradpur Union of Sitakunda upazila, Chittagong. Mr. Mustafiz is living in the present house for last 15 years. The homestead is of about 16 decimals land. Out of 2 sons and 6 daughters, all are married and staying in cities. He is living alone with his wife.

The homestead is composed of his dwelling house with a big front yard and a pond in northern site. He planted mixed species including timber, fruit and medicinal plants along the boundary and around the house. He planted mahagoni, akashmoni, eucalypts, rain tree, coconut, mango, kanthal and supari. He bought each seedling with 2 taka from the local nursery. Eucalyptus was the dominant species and they occupy the upper strata in the homesteads. *Eucalyptus* is known to him as Akashi because it tends to grow skywards in a short time (very fast growth). He is interested to plant trees because trees are safe and silent deposits of cash. At present market some of the trees valued about 8,000-10,000 taka (about 12 years old), and he expects to get at least 9 lac taka from his whole stock.

He heard about the negative effects of *Eucalyptus*, but never experienced it in his own homestead. He neither believe the controversy of high water absorption of eucalypts nor care about it. He is worried with rain tree because of spreading crown and casting shade to the adjacent crops. He is planning to sell the eucalypts at a time and will use the money for making a permanent house. Generally eucalypts timber is used for house construction, poles and furniture. In the area eucalypts have a good market also.

***Eucalyptus* plantation at road side:** Growth performance of 3-12 year old road side *Eucalyptus* plantation is shown in Table 6.5. The plot size was 10 m × 0.5 m. Highest volume (111.44 m^3) per hectare was found in 11 year old plantations, whereas lowest volume per hectare (24.65 m^3) was found in 3 year old plantations.

Table 6.5 Growth performance of *Eucalyptus* plantation at road side in Sitakunda Mirsarai

Spacing (m)	Stock ha^{-1} (number)	Age (year)	Height (m)	DBH (cm)	Survival %	Volume ha^{-1} (m^3)	MAI $m^3h^{-1}yr^{-1}$
1.66 × 1.66	3448	3	5.16	7.8	95	28.32	9.44
1.68 × 1.68	3260	3	5.00	7.6	92	24.65	8.22
1.75 × 1.75	2906	4	6.57	8.9	89	39.63	9.91
1.56 × 1.56	3287	5	5.59	9.7	80	45.28	9.06
1.30 × 1.30	2346	8	7.05	10.76	76	50.11	6.26
1.86 × 1.86	2168	9	6.69	13.23	75	66.50	7.39
1.75 × 1.75	2449	10	7.72	14.25	75	100.48	10.05
1.70 × 1.70	2491	10	7.54	14.8	72	107.73	10.77
1.88 × 1.88	1981	11	8.54	15.86	70	111.44	10.13
2.00 × 2.00	1700	12	9.13	16.38	68	109.08	9.09

***Eucalyptus* plantation established at fallow lands:** Growth performance of 3 to 11 year old *Eucalyptus* plantations at fallow lands is shown in Table 6.6. The plot size was 10 m × 10 m. Highest volume (131.28 m^3) per hectare was found in 9 year old plantations, whereas, lowest volume per hectare (19.93 m^3) was found in 4 year old plantations. Highest mean annual increment per hectare per year is 14.58 m^3 was found from 7 year old plantations. Lowest mean annual increment per hectare per year is 4.98 m^3 and was found in 4 years old plantations (Table 6.6)

Table 6.6 Growth performance of *Eucalyptus* species in fallow lands

Spacing (m)	Stock ha^{-1} (number)	Age (year)	Height (m)	DBH (cm)	Survival %	Volume ha^{-1} (m^3)	MAI $m^3h^{-1}yr^{-1}$
1.37 × 1.37	4635	3	3.20	7.87	87	24.05	8.02
1.78 × 1.78	2683	4	4.87	8.53	85	24.89	6.22
1.95 × 1.95	2235	4	4.98	8.27	85	19.93	4.98
1.50 × 1.50	3556	5	5.83	9.54	80	49.36	9.87
1.63 × 1.63	2860	5	5.20	10.06	76	39.39	7.87
1.79 × 1.79	2403	5	5.31	12.11	77	49.04	9.80
1.90 × 1.90	2022	6	5.94	14.31	73	64.45	10.74
1.82 × 1.82	2083	7	6.10	15.67	69	81.69	11.67
1.46 × 1.46	2862	9	7.00	15.82	61	131.28	14.58
2.92 × 2.92	1009	11	8.39	22.18	86	108.98	9.90

Case study: 2

Hazi Nurul Islam of 70 year old, have six daughters and 6 sons. All of them are married. His son Robiul Hossen, 28 year old informed us about the success story of eucalypt plantation. He has 48 acres of land and a pond of 20 decimal. *Eucalyptus* was planted at 3 ft x 3 ft spacing. About 15 years ago, Mr. Islam planted with an objective of getting short term income as this tree grows very fast on lands with new landfills. He has taken suggestions from nursery owners. At the age of 12, the trees attained an average girth of 39-40 inches and 30-40 feet log height. He sold 200 trees at the rate of 3,000 Taka each. He said that planting *Eucalyptus* is profitable than having a fixed deposit in the bank. He is planning to sell the remaining trees when he requires and meanwhile prices will be high.

Mr. Robiul Hosen is very pleased with eucalypts!

Eucalypts even in the front yard!

As demerits he mentioned that eucalypts takes much water and crop production reduces in the adjacent fields. He opined that *Eucalyptus* is more powerful than other trees. He also plants mahogoni, koroi, raintree, mangium, krishnochura, but eucalypts growth was superior in comparison to other trees. He opined that the people who do not have a piece of land to plant trees, no knowledge about trees, only they can blame eucalypts.

Eucalypts are widely used in house construction purposes. He personally used eucalypt for his own use and satisfy with the timbers. In Sitakunda, one of the most important uses of eucalypts branches is as support for bean. Each stake of 100 branches (stick) is sold at the rate of 600 Taka. That's why the whole Sitakunda and Mirsoroi area is dominating with eucalypt trees.

There is also variability on overall growth performance of *Eucalyptus* established at fallow lands. The reason may be due to seed quality, site quality and density. Some young plantations showed promising growth performances in comparison to old plantations, e.g., 3 years old plantations showed better performance in comparison to other plantations, because its site is in a fertile agricultural land (Table 6.6).

Case study 3

Mr. Bahar has a good deposit in Eucalypts

Mr. Abul Hossen Bahar, 45 year old of Choto Komol daha, Wahidpur village, Mirsarai upazila of Chittagong district planted eucalypts on 24 decimal flat lands in 2006. The land was not useable at that time because roads and highways kept their construction materials and bricks on the land. The land became unsuitable for agriculture, so getting no other options he planted eucalypt trees.

Reasons for planting Eucalyptus: In rainy season the land goes under water. He tried rain tree but they died. As second choice he planted eucalypts because of their fast growth and will allow him to get short term return. By now, the trees attain a merchantable height of about 20-25 feet and 10-15 inches diameter. Meanwhile, he sold about 100 poles for roads and highways construction work from where he received Taka 200,000. He also thinks to thin out some congested trees and expecting to have about one lac taka from that thinning operation. It will allow the remaining trees much space for better growth. Just after 5 years each trees will worth 5000 taka each.

Mr. Bahar has another roadside eucalypts plantation on around 2 decimal lands. Trees attained maximum height by this time. Eucalypts round wood will be sold at the rate of 500 taka per cft and each trees will sell around 5000 taka by now. He mentioned that *Eucalyptus* can be used for house construction purposes especially as beam, batti, paya, dasa etc.

Trees growing with very little care in waste lands

Average mean annual increments (MAIs) in different sites: Average MAI of eucalypts at homestead was very low (5.88 m^3) in comparison to other four sites (Table 6.7), because homestead encompasses many species other than *Eucalyptus* and has to compete with other species. About 50% plantations at pond bank were found as mix plantations and others were found as monoculture. It may also be the cause of poor average MAI than other three (crop field boundary, road side and fallow land) plantations. Similarly, crop field boundary, road side and fallow land mono-plantations were also variable. Crop field boundary and pond bank plantation showed highest average MAI than fallow land because they were in single row at the pond bank and boundary of agriculture land. These sites help the trees to get more nutrients, water and more sunlight in comparison to other plantation sites (Table 6.7)

Table 6.7 Age and MAI ($m^3h^{-1}yr^{-1}$) of eucalypts grown at different sites in Sitakunda-Mirsarai upa-zila

Plantation site	Average age (year)	($m^3h^{-1}yr^{-1}$)
Homestead	9.1	5.88
Pond bank	6.3	10.10
Crop field boundary	5.9	10.58
Roadside	7.5	9.03
Fallow land	5.9	9.37

6.3 *Eucalyptus* in Sirajgonj

Similar to Sitakunda and Mirsarai upa-zila of Chittagong, Sirajgonj district is popular for eucalypts plantation. Mr. Tashfiq and Ms Farhana from Independent University of Bangladesh had a field visit in Sirajgong to study the reasons of planting and trading eucalypts in the area. The team had interactions with nursery owners, homestead dwellers, cropland owners and share croppers, saw mill owner, furniture industry and market places to understand their perceptions about growing *Eucalyptus* and its uses. The findings of the study are as follows:

Case study 1. *Eucalyptus* in a private nursery

Md. Ali Jinnah Talukdar (55) has a nursery at Gurka, Beltola, Sirajgonj. He has established his nursery almost 17 years ago over 46.2 decimal of land. During 2011 he raised around 2,00,000 seedlings of 35 different species of which 40,000 are *eucalyptus* seedlings. In 2010 he raised 80,000 seedlings of eucalypts and during 2009 it was around 1,00,000 seedlings. He believed that gradually the market is getting saturated and the demand of the seedlings is gradually reduced and hence he raised only 40,000 seedlings this year (2011) in his nursery. The bulk of the seedlings are purchased by the traders from other districts such as Sylhet, Chittagong etc. They come with lorry and buy 3-4 thousands seedlings in a lot. Local consumers buy seedlings either to plant in their homesteads or on the marginal land including cropland boundaries or roadsides. Average cost is Taka 1-2 per seedlings, while wholesale rate of selling is Taka 3-4 per seedlings. The seedlings are sold when they are one year old.

Mr. Talukder said that there were two different types of *Eucalyptus* in his nursery and other nurseries in the area - white eucalyptus (which has long leaves, *E. camaldulensis*) and red eucalypts (which is shorter having semi round shaped leaves, *E. tereticornis*). The demand for white eucalyptus is more than the red one as it grows faster.

Talukder does not believe that eucalyptus has any negative effect on environment except high rate of water consumption. It grows faster and hence absorbs more water in comparison to other species. He said that it has medicinal value such as the leaves of eucalypts are used against cold and asthma; the wood is used to make good and durable furniture and one can have quick cash return from growing eucalypts. There is no need for any extra care or even using fertilizers or irrigation. The species is almost resistant to all pests and diseases. He rarely found seedlings affected by fungus and it could be controlled by spraying Thiovit (a fungicide). He argued that people complain against eucalypts for not nesting birds is because of the limited branches of the tree. Though the tree has small amount of leaves, the leaves are used as good fuel even in partial dry conditions.

The other species in his nursery includes akashmoni, mahogany, mango, litchi, jackfruit, olive, etc. He said that the demand for timber seedlings is gradually reducing due to space shortage for plantation, while demand for fruit trees (graft) are increasing which are expanding from cropland to homestead and all suitable areas.

Case study 2. *Eucalyptus* in croplands

Mr. Saiful Islam (34) planted 32 seedlings of eucalypts five years back on his cropland boundary following others in the area. His idea was that there would be minimum shade from the trees to prevent crops grown, and he would get additional benefit (cash) from the trees usually after 8-10 years.

As usual he had been cultivating his land for growing rice and other vegetables. At the initial stage, there was no negative impact of growing eucalypts on agri-crops, but since last two years he observed that paddy yield around each eucalypts tree (up to 12-18 inches distance) reduced significantly. Some of the rice crops died due to water stress.

Realizing that the trees are reducing the crop yield, he has sold out all those eucalypts last year and released the land for crop production. He felt that even after harvesting of the trees, he is not getting proper crop yield possibly because of chemicals released from the leaves of eucalypts grown around the crop field. However, he did not find any change in taste in rice produced from those fields.

Mr. Abdul Jalil (40) has 50 decimals of crop land. He planted 50 *Eucalyptus* around his crop field boundary 8 years ago. He did not observe any negative effect of growing *Eucalyptus* on the crop yield except consumption of more water by the trees. He provided additional irrigation when he observed any water deficit in his crop field. He says that he will get very good cash return from selling the trees and hence he took care of both the trees and the crops. He will sell those trees within a couple of years. He is expecting a very good cash return from selling the trees and planning for buying some lands for agriculture.

Case study 3. *Eucalyptus* in Homestead

Mr. Abu Sayeed inherited about 24 decimals of land from his father and he lives with his family depending on the land. Few years back there was a trend of planting eucalypts everywhere in Sirajgonj - Mr. Sayeed said. They know that the species grows faster and within 10 years the tree becomes mature without any special care and there is a demand for the wood of eucalypts in the market. Sayeed and his brother Musa planted 10 seedlings each of eucalypts in their homesteads. As expected the trees were growing fast and soon the trees were 15-20 feet in height.

The trees are matured now and he had offer for selling the trees. He thought that he would sell those trees and plant more eucalyptus in his homestead. Very recently he has observed that in his dwelling house there are some holes in the tin ceiling which are probably caused by the chemicals released from the leaves of *Eucalyptus*. He also speculated that due to height of the trees, it might invite thunder and affect them. Why Sayeed thought so? Is there any evidence of thunder storm under eucalyptus? Is there any scientific report on chemical reactions of eucalypt leaves with galvanized iron sheet? Possibly there is no such evidence but due to fear spread by the media or local people about eucalyptus, Sayeed is scared and has decided to remove his trees and not to replenish the area with the same species. But, his brother did not agree with Sayeed about the assumption and he decided to continue with planting more *Eucalyptus* in future for cash.

Case study 4. *Eucalyptus* in Roadside (private)

Eucalyptus along roadsides is quite common in Sirajgonj. It looks beautiful and does not prevent vision of traffic due to their minimum branching nature which is usually above 30 to 40 feet. The bole is straight, cylindrical and looks like RCC column.

In most cases, the trees are planted under benefit sharing arrangement between land owners and the communities. The trees are well protected. In one kilometer there are about 500-1000 trees. It is realized that the beneficiaries will have a very good cash return after felling the trees. People appreciated such plantation as the land would remain vacant otherwise had there been no eucalypts plantation. The species are not browsed by the cattle and hence survival rate is high. Roadside plantation with other species are also found which include sissoo, mahogany, raintree, etc but people prefer eucalypts as it provides less shade compared to other species.

Case study 5. *Eucalyptus* wood and their uses

Many people think that the eucalypts wood does not have any uses other than fuelwood. **Khoridul Islam** – a saw mill owner in Sirajgonj has furniture industry as well. More than 50% of the logs in his saw mill were eucalypts. He said that the harvesting season is February – March while he will have mainly eucalypts logs. People are earning lots of money from eucalypts. In response to the question whether it is difficult to saw *Eucalyptus*, Khoridul said- No, not at all. He fingered us to the carpenters to see how they are finishing the eucalyptus wood. He said that sawing is not difficult. The wood is highly durable and good for furniture, door and window frame, doors, etc. if the timber is mature and well treated. He said that per cft cost of wood is Taka 400-500, whereas other species cost less. It ranks fourth – whaere the first being teak, followed by mahogany and sissoo.

There is a demand for *Eucalyptus* furniture in Sirajgonj and neighboring areas. The wood is not affected by termites or fungus and is naturally durable. The finishing quality is also reasonably good. The price of wood varies with size of the log. There are variations in growth and hence age of wood is not important for fixing price of wood. The higher the diameter of logs, the more the price. Poles can be used for construction purposes (house posts), small planks are used for wooden ceilings and others are used for furniture.

Case study 6: *Eucalyptus* as woodlot

One might see a small patch of land covered with several *Eucalyptus* trees very densely in either cropland or raised land. Such plantations are called woodlots. **Md. Fazlur Rahman** has 33 decimal of land and a small chunk of land which is not suitable for crops has been used for planting 60 eucalyptus trees almost 9-10 years ago. He purchased each seedling at Taka 1/-. Almost all the seedlings survived and grew well though the diameter of some trees is relatively small. However, he is happy as he did not spend much time, energy and money for the woodlot.

He did not realize that the land would be that productive to give him good biomass of eucalyptus. The land was lying vacant but now he dreams of having good cash return from selling the eucalypts. He knew that eucalypts grow faster and he can harness quickest cash return. He also knew that the species consumes more water and affect other crops but as the land was fallow and there were no other crops around, he allocated the land for growing eucalyptus planting. Md. Fazlur Rahman did not provide irrigation or apply any fertilizer to the eucalyptus. His woodlot is close to a pond. He observed that water in the pond reduced by 5-6 feet after growing *Eucalyptus*!

He has already used some of the trees of this woodlot for making wooden window frames for his house. He will sell the remaining trees after 5-6 years. He expects to have a good return from selling the trees.

Case study 7: *Eucalyptus* Seedling markets of Sirajgonj

Seedlings are sold in Ghurka Bazaar. The rate of each seedling varies from Tk 5-10. The taller the seedlings, the higher the price. Though there are contradictions about negative effects of eucalypts, there is huge demand of the eucalyptus seedlings. People coming for weekly marketing were found to buy few seedlings for planting in their homestead or marginal land. There were 10 businessmen who sell *Eucalyptus* seedlings of different sizes and ages.

There is no public forest in Sirajgonj. The requirement of wood and fuelwood are met from the trees grown in homestead, marginal land, road sides and along the boundaries of cropland. Tree planting in non-forest land is definitely a noble initiative as it meets the demand of wood and wood products in one hand and reduces environmental pollution. Planting fast growing trees that has timber value and can be used for making furniture, doors and windows should be a right choice from environmental concern, but when such tree impair crop production through their allelopathic effect or consumes more water reducing ground water level might pose question of its effectiveness. There are controversies about environmental degradation of growing *Eucalyptus*. There is no systematic study on the impact of growing eucalyptus in Bangladesh except some media report. However, Institute of Forestry and Environmental Sciences have some research reports in recent time. The people who have been planting eucalypts in their homesteads came up with contradictory information – some says it does not affect environment while other says that it takes more water and due to water stress, the crop yield is reduced. Some attempted to provide supplementary irrigation to reduce water stress for crop production. Thus, it is evident that where water is abundant, the species may perform better without affecting environment. So, one of the preferred site for growing eucalypts should be along the river or canal bank, pond bank and other water bodies.

Though people had the impression that the use of eucalypts is limited to fuelwood, but it is clear from the study that the wood is highly durable and can be used for furniture, door and window frames. Moreover, the cost of wood is within the range of middle class or lower middle class. Thus, growing the species in non-forest land is reducing the pressure on forests and biodiversity.

However, one has to be careful about invasiveness of certain species. Conservation of biodiversity is essential for environmental equilibrium. Monoculture or commercial cultivation of one or few species is a threat to biodiversity. It pushes out some of the indigenous species making them either endangered or extinct. Moreover, it disposes the species towards pests and diseases and depletion of soil nutrients. The loss thus occur is huge and hence we must consider conserving indigenous tree species.

Whether eucalypts is environment friendly or not – it is difficult to comment from a short visit but it is realized that the people have been planting this species as cash crop and it gives much higher return compared to any other alternative crop production. For example, in an acre area if 1200 seedlings are planted and harvested after 10 years, with casuality of 50%, still 600 trees would survive. If each tree fetches Tk. 5000, at the end of 10 years, the return would be Tk. 3.0 million. If the investment cost is Tk. 0.2 million, then net return is Tk. 2.8 million.

However, it consumes more water. Northern Bangladesh is semi-arid in nature. If water level goes further down it will be highly damaging for agriculture. Due to conversion of agricultural land the yield of staple crops will be reduced. Considering food security, conversion of agricultural land for non-agriculture should be discouraged. Whether the leaves of eucalypts have allelopathic effect on soil, tin roof, crop production or others need further study.

Chapter 7

Conclusion

Though the *Eucalyptus* is conspicuously successful in many countries, some governments, organizations and individuals have raised concerns about alleged adverse impacts of these species. The concerns about the impacts of *Eucalyptus* are depletion of water resources, deterioration of soil and wildlife, allelopathic effects, etc. Nonetheless, some of the criticisms in Bangladesh have been caused by pessimistic expectations rather than by ecological effects. *Eucalyptus* has often been heralded as wonder fast grown tree species which will bring immediate solutions to local wood fuel crisis and reduce erosion problems. When these ambitious expectations are followed by failure or poor plantings because of wrong species selection or seed sources or wrong species-site matching, the local peoples or the Forest Department are disappointed with the poor field performances and returns.

Bangladesh has an immense scope and opportunity in extending plantation forests in barren, marginal and degraded forest areas. Whereas, Bangladesh is importing timber from more than 23 countries (**Figs. 93 and 94**) and the trend is increasing day by day at the expense of hard earning foreign currencies. Richard and Hassan (1989) studied the suitability of Bangladesh soil for growing eucalypts on land capability classes. About 4,50,000 ha were found suitable for eucalypt plantation. These areas may produce 3-4 times more biomass and 6-8 times more stem wood on short rotations with eucalypt than the present forest crops

Figure 93. Import of timber in Bangladesh is increasing through Teknaf port

Figure 94. Workers busy with loading sawn timbers in Teknaf port

(Munshi 1986). Chowdhury(1993) studied growth potential of *E. camaldulensis*, *Acacia auriculiformis* and *A. mangium* by site index method of growth and showed *Eucalyptus* performed better than *Acacia*.

Huge population in Bangladesh is unemployed and if they are involved in plantation programs in available lands (**Fig. 95**), the environment of the country will improve and the gap between demand and supply of forest produces will be minimized.

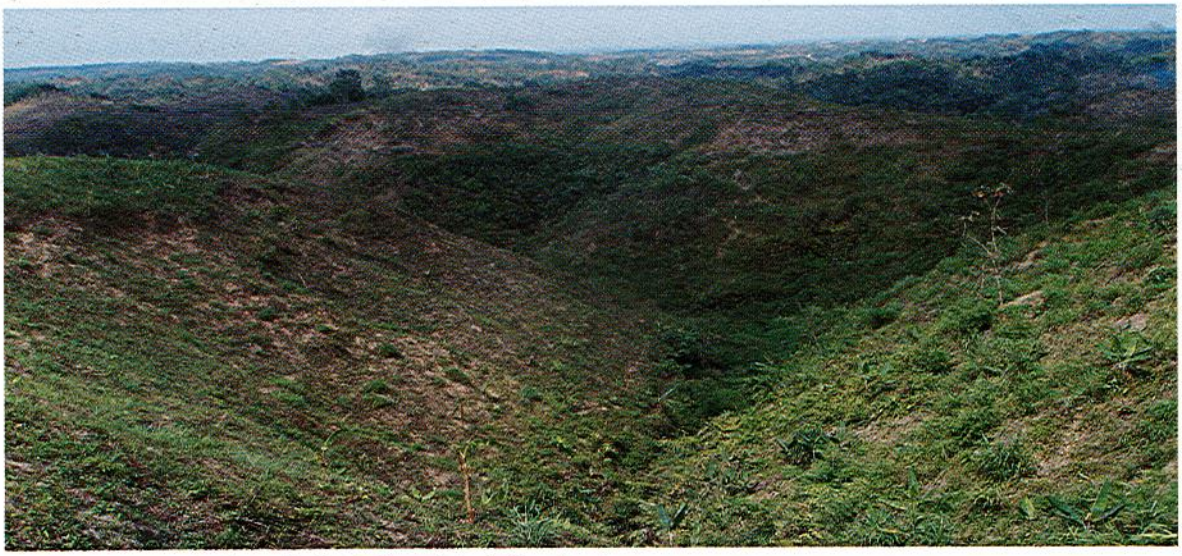


Figure 95. Huge lands available in Bangladesh for planting

The controversies of environmental degradation by planting eucalypts are not strongly supported by scientific findings and professional experiences. Social survey also supports the planting programs for immediate return from the plantations. However, native species must be given priority for plantation programs. If there is no suitable alternative to meet the immediate requirements, exotics may be planted in limited areas. Instead of mono-plantation, mix plantations must be given priority, so that multiproduct may be available from the plantations. Mixed plantations are able to solve many controversies of environmental issues of monoplantations (**Fig. 96**).

Figure 96. Mixed plantations solve many problems of exotics!

Chapter 8

References

Abd-Alla, M.F., El-Negoumy, S.I., El-Lakany, M.H. and Saleh, N.A.M. 1980. Flavonoids, glycosides and the chemosystematics of *Eucalyptus camaldulensis*. *Phytochemistry*, 19(2): 2629-2632.

Abedin, M.J., Lai, C.K. and Ali, M.O. (eds.). 1990. *Homestead Plantation and Agroforestry in Bangladesh*. Bangladesh Agricultural Research Institute, Joydebpur.

ACIAR. 1992. *Eucalypts: Curse or Cure?* Canberra, Australia: Australian Centre for International Agricultural Research, p.6.

Adegbehin, J.O. 1983. A preliminary survey of growth of *Eucalyptus* species in the Sudan and Guinea zones and Montane areas of Nigeria. *International Tree Crops Journal*, 2(3-4): 273-289.

Agnihotri, Y., Singh, S., Sud, A.D. and Singh, S. 1989. Growth statistics of different species of *Eucalyptus* tried in Shivalik foothills. *Indian Journal of Forestry*, 12(1):25-28.

Ahmed, G.U. 1990. Survival percentage and growth statistics of some plantation species at the Chittagong University Campus. *Chittagong University Studies Part II, Science*, 14(1): 45-50.

Ahmed, I.U. 2003. Forest Management: Bangladesh Perspective (In Bengali), *Aranya* 11(6): 19-28.

Ahmed, F.U. and Akhter, S. 1995. Problems and prospects of *Eucalyptus*. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.), *Eucalyptus in Bangladesh, Proceedings of the National Seminar held at Bangladesh Agricultural Research Council*, Dhaka on April 16.1994, pp. 42-53.

Ahmed, F.U. 2001. Agroforestry in Bangladesh with special reference to Northern Bangladesh. ***In:*** *Proc. National Workshop on Agroforestry*. September 16-17, Gazipur, Bangladesh, pp. 1-10.

Ahmed, N., Hussain, F. and Akram, M. 1982. The allelopathic potential of *Eucalyptus tereticornis* Sm. *Pak. Journal Botany*, 14:15-16.

Ahmed, N., Hussain, F. and Akram, M. 1984. The allelopathic potential of *Eucalyptus tereticornis* Sm. *Pak. J. Sci. Ind. Res.*, 27**:** 88–91.

Ahmed, R., Hoque, A.T.M.R. and Hossain, M.K. 2008. Allelopathic effects of leaf litters of *Eucalyptus camaldulensis* on some forest and agricultural crops. *J. For. Research*, 19(1):19-24.

Ahmed, R., Redowan, M., Uddin, M.S. and Hossain, M.K. 2007a. A pot experiment to evaluate the allelopathic potential of leaf extracts of *Eucalyptus camaldulensis* on five common agricultural crops. *J. Subtrop. Agric. Res. Dev.*, 5(3):280-285.

Ahmed, R., Redowan, M., Uddin, M.S. and Hossain, M.K. 2007b. *Eucalyptus* as a agroforestry component in the homestead and agricultural field of Sitakunda, Bangladesh. *Int. J. Sustain. Agril. Tech.*, 3(3):46-51.

Ahmed, R., Uddin, M.B. and Hossain, M.K. 2004. Allelopathic effects of leaf extracts of *Eucalyptus camaldulensis* Dehn. on agricultural crops. *Bangladesh Journal of Botany,* 33: 79-84.

Alam, M.K., Mohiuddin, M. and Guha, M.K. 1991. *Trees for low-lying areas of Bangladesh.* Bangladesh Forest Research Institute, Chittagong, p. 77.

Alam, M.S. and Masum, K.M. 2005. Status of homestead biodiversity in the offshore island of Bangladesh. *Research Journal of Agriculture and Biological Sciences*, 1(3): 246-253.

Ali, M. 1995. Environmental considerations for *Eucalyptus* plantation management in Bangladesh. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.) *Eucalyptus in Bangladesh, Proceedings of the National Seminar held at Bangladesh Agricultural Research Council*, Dhaka on April 16, 1994. pp. 54-69.

Ali, M. 1996. Status, aspects and environmental considerations of *Eucalyptus* planting in Bangladesh. ***In:*** M. Kashio and K. White (eds.) *Report submitted to the Regional Expert Consultation* on *Eucalyptus*. 4-8 October, 1993. RAP Publication 1996/44, Vol. 2, FAO, Bangkok, Thailand, pp 1-16.

Ali, M.O., Yakub M. and Bhattacharjee, D. K. 1974. Physical and Mechanical Properties of Toon (*Cedrela toona*), Bhadi (*Lannea coromendelica*) and *Eucalyptus* (*Eucalyptus citriodora*). Bulletin 3, Timber Physics Series, Bangladesh Forest Research Institute, Chittagong, p. 27.

Al-Mousawi, A.H and Al-Naib, F.A.G. 1975. Allelopathic effect of *Eucalyptus microtheca*. *J. Univ. Kuwait, (Science)*, 2:59-60.

Al-Mousawi, A.H. and Al-Naib, F.A.G. 1976. Volatile growth inhibitors produced by *Eucalyptus microtheca. Bull. Biol. Res. Center.* 7:17-23.

Altrell, D., Saket, M., Lyckeback, L., Piazza, M., Ahmad, I.U., Banik, H., Hossain, M.A.A. and Chowdhury, R.M. 2007. *National forest and tree resources assessment 2005-2007.* Bangladesh Forest Department, Ministry of Environment and Forest; Bangladesh Space Research and Remote Sensing Organization, Ministry of Defence, Food and Agriculture Organization of the United Nations. pp. 192.

Amin, S.M.R., Ali, M.O. and Fattah, M.I.M. (eds.). 1995. *Eucalypts in Bangladesh. Proceedings of a Seminar held at the Bangladesh Agricultural Research Council*, Dhaka on April 6, 1994. p. 73.

Anderson, E. 1993. *Plants of Central Queensland.* Brisbane, Australia: Department of Primary Industries. Queensland Government Printer.

Anonymous. 2006. Bangladesh Economic Review. Economic Adviser's Wing, Finance Division, Ministry of Finance, Govt. of the Peoples Republic of Bangladesh.

Anonymous. 2007. Eucalypts for Cold Climates, Northern Hemisphere Cultivation. ***In:*** *Australian National Botanic Gardens - growing, studying and promoting Australia's flora*. Updated on Thursday, 13 December, 2007 (www.anbg.gov.au/gnp/cold-climate/eucalypts-cold-climates.html) Latest accessed on 2.29 PM 15th April, 2011.

Antonio, P.S.S.F., Teresinha, J.D.R.R., Luis, A.R. and Ricardo, A.R. 1999. Effects of aqueous extracts of *Leucaena* on germination and radicle elongation of three forage grasses. *Recent Advances in Allelopathy: A Science for the Future,* 1: 391-396.

Ara, S., Gafur, M.A. and Islam, K.R. 1989. Growth and biomass production performance of *Acacia auriculiformis* and *Eucalyptus camaldulensis* reforested in the denuded hilly lands. *Bangladesh J. Bot.*, 18(2):187-195.

Aryal, U.K., Hossain, M.K., Koirala, B., Mridha, M.A.U, Xu, H.L. and Umemura, H. 1999. Effect of pure and mixed planting of *Eucalyptus camaldulensis* Dehn. and *Albizia procera* (Roxb.) Benth. on growth, biomass yield and soil fertility. ***In:*** *Nature Farming and Sustainable Environment*, II: 57-62.

Ashton, D. H. and Willis, E. J. 1982. Antagonisms in the regeneration of *Eucalyptus regnans* in the mature forest, ***In:*** *The Plant Community as a Working Mechanism*, Newman, E. I., Blackwell Scientific, Oxford, p.113.

Awe, J.O. and Shepherd, K.R. 1975. Provenance variation in frost resistance in *Eucalyptus camaldulensis* Dehn. *Australian Forestry*, 38(1):26-33.

Ayling, R.D. and Martins, P.J. 1981. The growing of eucalypts on short rotation in Brazil. *Forestry Chronicle*, 57(1): 9-16.

Baker, R.T. and Smith, H.G. 1920. *A research on the Eucalyptus and their essential oils*, 2nd ed., Government printer, Sydney, p. 472.

Banerjee A.K. 1972. Fertilisation of *Eucalyptus tereticornis* sm. in the lateritic areas of West Bengal. *West Bengal Forests*, 2(1):7.

Banglapedia. 2003. *National Encyclopedia of Bangladesh*, Vol. 4, S. Islam (Chief editor), Asiatic Society of Bangladesh, Nimtali, Dhaka.

Banik, R.L. and Alam, M.K. 1995. Effects of *Eucalyptus* plantation in Bangladesh: A brief review. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.) *Eucalyptus in Bangladesh, Proceedings of the National Seminar* held at Bangladesh Agricultural Research Council, Dhaka on April 16.1994, pp. 15-26.

Banik, R.L., Islam, S.A.M.N., Mannan, M.A. and Das, S. 1997. A Manual for Clonal Propagation of Hybrid *Acacia* and *Eucalypt. camaldulensis*. Bull. 2, Tree Propagation Series, BFRI, Chittagong, p. 18.

Bansal, G.L., Nayyer, H. and Bedi, Y.S. 1992. Allelopathic effect of *Eucalyptus macrorrhyncha* and *E. youmanii* on seedling growth of wheat (*Triticum aestivum*) and radish (*Raphanus sativus*). *Ind. J of Agric. Sci.*, 62(11): 38-141.

Baruah, P., Sharma, R.K., Singh, R.S. and Ghosh, A.C. 1996. Fungicidal activity of some naturally occurring essential oils against *Fusarium moniliforme*. *J. Essential Oil Res.*, 8: 411-441.

Basak, A.C. 1993. Pink disease on *Eucalyptus camaldulensis* in Bangladesh. *Bang. J. of For. Sci.*, 22 (1 & 2): 68-70.

Basak, A.C. 1997. Heart rot of *Acacia mangium* in Bangladesh. *Ind. J. For.*, 20(1):61-66.

Bashir, J., Nair, P.K.R. and Kurira, P.W. 1989. Comparative growth performance of some multipurpose trees and shrubs grown at Machakos, Kenya. *Agroforestry Systems*, 9: 17-27.

BBS. 1999. Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh.

BBS. 2005. Statistical Yearbook of Bangladesh 2004. Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh.

Begum, S. 1995. Leaf spot and twig blight on *Eucalyptus camaldulensis* Dehrth. caused by *Colletotrichurn gleosporioides* (Penz.) Sacc. in Bangladesh. *Bang. J. For. Sci.*, 24 (1): 30-35.

Bhuiyan, A.A. 1979. Afforestation of unclassed state forests lands areas in Chittagong Hill Tracts of Bangladesh. *Bano Biggyan Patrika*, 8(1&2):64-70.

Bhuiyan, A.A. 1995. Prospects of *Eucalyptus* plantation in Bangladesh: Field performance experience. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.), *Eucalyptus in Bangladesh, Proceedings of the National Seminar* held at Bangladesh Agricultural Research Council, Dhaka on April 16, pp 34-41.

Bhuiya, M.S.U., Choudhury, N.S. and Hossain, S.M.A. 2001. Agroforestry research and development in two FSR sites of Bangladesh Agricultural University. ***In:*** M.F. Haq, M.K. Hasan, S.M. Asaduzzaman and M.Y. Ali (eds.), *Proceedings of a National Workshop on Agroforestry Research* held in September 16-17, 2001 in Gazipur, Bangladesh, pp.11-18.

Bhuiyan, M.K., Zashimuddin, M., Latif, M. A. and Khan, S. A. 1986. Effect of initial spacing on the survival and growth of *eucalyptus*. *Chittagong University Studies, Part 2 Science,* 10 (1 & 2): 115-121.

Blake, T.J. 1980. Effects of coppicing on growth rates, stomatal characteristics and water relations in *Eucalyptus camaldulensis* Dehn. *Aust. J. Plant Physiol.*, 7:81-87.

Blake, T.J. 1983. Coppice systems for short rotation intensive forestry: the influence of cultural, seasonal and plant factors. *Aust. For. Res.*, 13:279-291.

Blake, S.T. and Roff, C. 1988. *Honey Flora of Queensland*. Brisbane, Australia: Department of Primary Industries.

Boer, E. 1997. *Eucalyptus tereticornis* J.E. Smith. ***In:*** I. Faridah Hanum, & L.J.G. van der Maesen (eds.), *Plant Resources of South-East Asia No. 11: Auxiliary plants.* Backhuys Publisher, Leiden, The Netherlands, pp 137-140.

Boland, D.J. (ed.). 1989. *Trees for the Tropics: Growing Australian Multipurpose Trees and Shrubs in Developing Countries.* ACIAR Monograph No. 10. p. 247.

Boland, D.J., Brooker, M.I.H., Chippendale, G.M., Hall, N., Hyland, B.P.M., Johnston, R.D., Kleinig, D.A. and Turner, J.D. 1984. *Forest trees of Australia*. 4th ed. Melbourne: Thomas Nelson and CSIRO, p. 687.

Boland, D.J., Brooker, M.I.H., Turnbull, J.W. and Kleinig, D.A. 1980. *Eucalyptus* seed. Canberra, Australia: Division of Forest Research, CSIRO, p.191.

Boland, D.J., Brophy, J.J. and House, A.P.N. (eds.). 1991. *Eucalyptus leaf oils: use, chemistry, distillation and marketing*. Melbourne, Australia: Inkata Press, p. 252.

Booth, T.H. and, Pryor, L.D. 1991. Climatic requirements of some commercially important eucalypt species. *Forest Ecology and Management*, 43(1-2): 47-60.

Bootle, K.R. 1983. *Wood in Australia. Types, properties and uses*. Sydney, Australia: McGraw-Hill Book Company, p. 443.

Bowman, D.M.J.S. and Kirkpatric, J.B. 1986. Establishment, suppression and growth of *Eucalyptus delegantensis* R. T. Baker in multi-aged forests. III. Intraspecific allelopathy, competition between adult and juvenile for moisture and nutrients, and frost damage to seedlings, *Aust. J. Bot.*, 34:81.

Brooker, M.I.H. and Kleinig, D.A. 1983. *Field guide to eucalypts*. Volume 1. South-Eastern Australia, p. 288.

Brooker, M.I.H. and Kleinig, D.A. 1990. *Field Guide to the Eucalypts*: Volume 2 South-Western and Southern Australia. Melbourne, Australia: Inkata Press.

Brooker, M.I.H. and Kleinig, D.A. 1994. *Field Guide to Eucalypts*. Volume 3. Northern Australia. Sydney, Australia: Inkata Press.

Brundrett, M., Beegher, N., Dell, B., Groove, T. and Malajczuk, N. 1996. Working with mycorrhizas in Forestry and Agriculture. ACIAR Monograph 32, p. 374.

Chaturvedi, A.N. 1973. Rotation in *Eucalyptus* hybrid plantations. *Indian Forester*, 99(4):205-214.

Chaturvedi, A.N. 1983. *Eucalyptus* for commercial farming. *National Workshop on Agroforestry*. Karnal, India, July 21-23.

Chaudhury, R.A. 1982. Afforestation of denuded hills of Chittagong and Chittagong Hill Tracts. *Proceedings of Second Bangladesh National Conference on Forestry*, Dhaka, pp 1-5.

Chauhan, J.M.S., Prabha B., Kapoor, M.L. and Rawat, M.S. 1996. In vitro clonal propagation of *Eucalyptus* hybrid FRI-4 (*E. tereticornis* sm. X *E. camaldulensis* Dehn.). *Annals of Forestry*, 4(2):186-199.

Chinnamani, S. and Gupte, S.C. 1966. A note on stump planting of some eucalypts and black wattle in the Nilgiris. *Indian Forester*, 92(11): 667-668.

Chippendale, G.M. 1988. *Eucalyptus* (Myrtaceae). Flora of Australia, 19. Canberra, Australia: Australian Government Publishing Service.

Chou, C.H. and Kuo, Y.L. 1986. Allelopathic exclusion of understory by *Leucaena leucocephala* (Lam.) de wit. *J. Chem. Ecology*, 12:1431-1448.

Chou, C.H. and Waller, G.R. 1980. Possible allelopathic constituents of *Coffea arabica*. *J. Chem. Ecol.*, 6:643-653.

Chowdhury, J.A. 1993. *Final Report of the Resource Survey Consultant*. Thana Afforestation and Nursery Development Project, Bangladesh.

Chowdhury, M.K. and Sattar, M.A. 1993. Homestead and Cropland Agroforestry Practices in the High Ganges River Flood Plain. ***In:*** *Agroforestry Farming Systems Linkage in Bangladesh*. BARC-Winrock International, Dhaka, Bangladesh.

Chowdhury, Q.I. 1999. Bangladesh: Country Overview. ***In:*** Q.I. Chowdhury (Ed.), *Bangladesh State of Environment Report 1999*, Forum of Environmental Journalists of Bangladesh, Dhaka, pp. 1-14.

Chowdhury, R.A. 1994. History and importance of Sal forests and current management status. ***In:*** *Proceedings of the National Workshop on Agroforestry for the Degraded Sal Forests*. Workshop held at the Bangladesh Agricultural Research Council, Dhaka on Nov 26-Dec 1, BARC, FD and Asia Pacific Agroforestry Network, Bangladesh, pp. 9-25.

Clemson, A. 1985. Honey and pollen flora. Melbourne, Australia: Inkata Press, p. 263.

Costin, A. B. 1954. *A Study of the Ecosystem of the Monaro Region of New South Wales with Special Reference to Soil Erosion*, Government Printer, Sydney.

Cremer, K. W.1990. *Trees for Rural Australia*. Inkata Press, Melbourne.

Dabral, B.G. 1970. Preliminary observations on potential water requirement in *Pinus roxburghii*, *Eucalyptus citriodora*, *Populus casale* (488) and *Dalbergia latifolia*. *Indian Forester*, 96(10): 775-780.

Darrow, W.K. 1997. Eucalypt site-species trials in Zululand: results at four years of age. *ICFR Bulletin Series*, No. 3/97.

Das, D.K. 1990. *Forest Types of Bangladesh*. Bulletin 6, Plant Taxonomy Series. Bangladesh Forest Research Institute, Chittagong, Bangladesh.

Das, S. 1982. The forest management practice in Bangladesh. Proceedings of Second Bangladesh National Conference on Forestry, Dhaka, p. 6-18.

Das, S. 1984a. *Nursery Techniques for Eucalyptus Species*. Bulletin 1, Silviculture Research Division, BFRI, Chittagong (In English and Bangla), p. 33.

Das, S. 1984b. *Management Technique for Raising Eucalyptus Plantations*. Bulletin 2, Silviculture Research Division, BFRI, Chittagong. (In English and Bangla).

Das, S. and Siddiqi, N.A. 1985. *The Mangrove and Mangrove Forests of Bangladesh*, Mangrove Silviculture Division, Bulletin no. 2, Bangladesh Forest Research Institute, Chittagong, Bangladesh, p. 142.

Davidson J. 1973. *Redistribution of nutrients in the surface soils of the Pillage Region*. Dissertation for Botany Major, University of New England, Australia, p. 95.

Davidson, J. 1985a. Setting aside the idea that eucalypts are always bad. UNDP/FAO Project BGD/79/017, Working Paper No. 10, Dhaka, p. 26.

Davidson, J. 1985b. Ecological and social aspects of eucalypts when used as exotics. ***In:*** J. Davidson and S. Das (eds.), *Eucalypts in Bangladesh - a Review.* Silviculture Bulletin No. 6. Chittagong. Bangladesh Forest Research Institute, pp. 13-49.

Davidson, J. 1988. Breeding eucalypts in tropical countries. Proceedings Vol. 5. Albury-Wodonga, Australia: Australian Bicentennial Forestry Conference.

Davidson, J. 1993a. Ecological aspects of *Eucalyptus* plantations. ***In:*** *Proceedings of the Regional Expert Consultation* on *Eucalyptus*. 4-8 October 1993. RAP Publication 1996/44, Vol. 1, FAO, Bangkok, Thailand, pp. 35-72.

Davidson, J. 1993b. Domestication and breeding programme for *Eucalyptus* in the Asia-Pacific region. UNDP/FAO Regional Project on Improving Productivity of Man-Made Forests Through Application of Technological Advances in Tree Breeding and Propagation (RAS/91/004-FORTIP). Los Baños, Philippines: FAO of the United Nations.

Davidson, J. and Das, S. 1985. *Eucalypts in Bangladesh- A Review.* Bull. 6, Silv. Res. Div. Bangladesh Forest Research Institute, Chittagong, Bangladesh, p. 246.

Davidson, J., Das, S., Khan, S.A., Latif, M.A. and Zashimuddin, M. 1985a. *Tree Volume Tables for Small Eucalypt Round Wood in Bangladesh.* Bulletin 4, Silviculture Research Division, BFRI, Chittagong, p. 71.

Davidson, J., Das, S., Latif, M.A., Zashimuddin, M. and Khan, S. A. 1985b. *Provenance trials of Eucalyptus established in 1978.* Bulletin No. 6, Bangladesh Forest Research Institute, Chittagong, pp. 91-105.

Davidson, J., Das, S., Latif, M.A. and Zashimuddin, M. 1985c. *Eucalypt Biomass Production.* Bull. No. 6, Silviculture Res. Division, Bangladesh Forest Research Institute, Chittagong, pp. 135-165.

Davidson, J., Das, S., Latif, M..A. and Zashimuddin, M. 1985d. *Eucalyptus species elimination trials.* Bulletin No. 6, Silviculture Division, Bangladesh Forest Research Institute, Chittagong, pp. 72-89.

Davidson, J.1995. Ecological aspects of *Eucalyptus* plantations. *Proceedings of the Regional Expert Consultation on Eucalyptus*, 4-8 October, 1993, vol.1, RAPA publication:1995/6. FAO Regional Office for Asia and the Pacific, Bangkok, pp. 35-72.

Dawson, T.E. and Pate, J.S. 1996. Seasonal water uptake and movement in root systems of phraeatophytic plants of dimorphic root morphology: a stable isotope investigation. *Oecologia*, 107:13-20.

Dayal, R. and Maheshwari, M.L. 1985. Terpenoids of the essential oil of *Eucalyptus*. *Indian Forester*, 111:1076-1079.

del Moral, R. and Muller, C.H. 1970. Allelopathic effect of *Eucalyptus camaldulensis*. *The American Midland Naturalist*, 83:254-282.

del Moral, R., Willis, R.J., and Ashton, D.H. 1978. Suppression of coastal heath vegetation by *Eucalyptus axteri. Aust. J. Bot.,* 26:203.

Dhillon, G.S., Singh, S., Ghillon, M.S. and Attiwal, A.S. 1982. Developing agri-silvicultural practices: studies on the shading effect of *Eucalyptus* on the yield of adjoining crops. *Indian J. Ecol.*, 9: 228-236.

Dino, N. and Luigi, P. 1966. Components of *Eucalyptus* wood II. Proanthocyanide with biflavin structure from *E. camaldulensis. Gazz. Chem. Ital.*, 96(6): 803-19.

Doran, J,C. and Brophy, J.J. 1990. Tropical red gums - a source of 1,8-cineole-rich *Eucalyptus* oil. *New Forests*, 4(3):157-178.

Doran, J.C. and Turnbull, J.W. 1997. *Australian trees and shrubs: Species for land rehabilitation and farm planting in the tropics*. ACIAR Monograph No. 24. p. 384.

Doran, J.C. and Wongkaew, W. 1997. *Eucalyptus camaldulensis* Dehnh. ***In:*** F.I. Hanum and L.J.G. van der Maesen, (eds.) *Plant Resources of South-East Asia No. 11. Auxiliary Plants*. Leiden, the Netherlands: Backhuys Publishers, pp. 132-137.

dos-Santos, V.L., Muchovej, R.M., Borges, A.C., Neves, J.C.L. and Kasuya, M.C.M. 2001. Vesicular-arbuscular-ecto-mycorrhiza succession in seedlings of *Eucalyptus* spp. *Braz. J. Microbiol.*, 32(2):81-86.

Eldridge, K.G., Davidson, J., Harwood, C.E. and Van Wyk, G. 1993. *Eucalypt domestication and breeding*. Clarendon Press. Oxford, UK, p. 288.

El-Gammal, A.A. and Mansour, R.M.A. 1986. Antimicrobial activities of some flavonoid compounds. *Zentralbiology Mikrobiology*, 141: 561–565.

Evans, J. 1992. *Plantation Forestry in Tropics*, 2nd ed., Clarendon press, Oxford, p. 403.

Fadel, H., Marx, F., El-Sawy, A. and El-Ghorab, A. 1999. Effect of extraction techniques on the chemical composition and antioxidant activity of *Eucalyptus camaldulensis* var. *brevirostris* leaf oils. *Zeitschrift Für Lebensmitteluntersuchung Und -Forschung A*, 208: 212-216 (Abstracted).

FAO. 1975. Pest and diseases of fast growing hardwoods, ***In:*** *2nd FAO/IUFRO World Technical Consultation on Forest diseases and Insects*, New Delhi, India, 7-12 April 1975, Rome, Italy.

FAO. 1988. *The eucalypt dilemma*. FAO, Rome, p. 26.

FAO. 2006. *Global Forest Resource Assessment 2005*. Food and Agriculture Research organization, FAO Forestry Paper 147. FAO, Rome.

Farid, A.T.M., Iqbal, A. and Karim, Z. 1992. Soil erosion in Chittagong Hill Tract and its impact on nutrient status of soils. *Bangladesh Journal of Soil Science*, 23 (1&2): 92-101.

FD (Forest Department). 2004. *Nursery and Plantation Manual*. Forest Department, Ministry of Environment and Forests, Government of Bangladesh.

Florence, R.G. 1986. Cultural problems of *Eucalyptus* as exotics. *Commonwealth Forestry Review*, 65:141-163.

Florence, R.G. 1990. *Perceptions of the eucalypt as an exotic: an ecological interpretation.* International Symposium on *Eucalyptus*, Zhanjiang, China, November 1990, p. 21.

Florence, R.G. 1996. *Ecology and silviculture of eucalypt forests.* Melbourne: CSIRO Publishing.

FMP (Forestry Master Plan).1992. *Forest Institutions, Forestry Master Plan*, ADB (TA No. 1355- Ban), UNDP/FAO BGD 88/025, p.191.

FMP (Forestry Master Plan).1993. *Forestry Master Plan: Main Plan-93/2012, vol.1*, Ministry of Environment and Forest, Govt. of Bangladesh, p.162.

Ford-Robertson, F.C. (ed.). 1971. *Terminology of forest science, technology, practice and products.* IUFRO/Society of American Foresters, Washington DC.

Forestry Compandium. 2005. Forestry Compandium, CD Edition, ISBN: 0851990312, CAB International, UK.

Foroughbakhch, R., Háuad, L.A., Badii, M.H. and Earl, P.R. 1997. Establishment and growth of five *Eucalyptus* species in north-eastern Mexico. *Forest, Farm, and Community Tree Research Reports*, 2:46-50.

Frood, D. 1979. *Dynamics of a Post-1951 Fire Healthland, Tidal Overlook, Wilson's Promontory, Victoria.* B. Sc. (Hons.) thesis, University of Melbourne, Australia.

FSP. 2004. Participatory Forestry Newsletter, Bulletin No. 1. May 2003. Forestry Sector Project, Forest Department, Dhaka.

Gaba, R.K. 1987. Role of allelopathy in social forestry. ***In:*** P.K. Khosla and R.K. Kholi (eds.) *Social forestry for rural development.*, ISTS, Solan, pp. 228-234.

Gavenda, B. 2000. *Soils and Carbon Sequestration. Kona Soil and Water Conservation District* Field Tour, Pu'u Waawaa, North Kona, USDA-NRCS, Kealakekua, Hawaii.

George, M. 1978. Interception, stemflow and throughfall in a *Eucalyptus* hybrid plantation. *Indian Forester*, 104 (11):719-726.

George, M. 1979. Nutrient return by stem flow, throughfall and rainwater in a *Eucalyptus* hybrid plantation. *Indian Forester*, 105(7):493-499.

George, M. 1982. Litter production and nutrient return in *Eucalyptus* hybrid plantations. *Indian Forester*, 108(4): 252-260.

Gibson, A., Bachelard, E.P. and Hubick, K.T. 1995. Relationship between climate and provenance variation in *Eucalyptus camaldulensis* Dehn. *Australian Journal of Plant Physiology*, 22(3):453-460.

Guenther, E. 1950. *The Essential Oils*, Vol. 4. van Nostrand Co.,, New York.

Gujral, R.S. 1990. Homestead and Agroforestry in Asia. ***In:*** M.Z. Abedin, C.K. Lai and M.O Ali (eds.), *Homestead plantation and agroforestry in Bangladesh.* BARI, Gazipur, Bangladesh, pp. 1-7.

Gupta, A.C. and Raturi, D.P. 1984. Distribution of organic matter and nutrient content in a *Eucalyptus* hybrid plantation on lateritic soil in West Bengal. *Indian Forester*, 110(2):122-128.

Gurgel Filho, O.A. and Corsini, C.A. 1973. Silvicultural characters of *Eucalyptus citriodora*. *Brasil Florestal*, 4(14):14-18.

Hasan, M.K. and Alam, A.K.M.A. 2006. Land degradation situation in Bangladesh and role of Agroforestry. *J. Agric. Rural. Dev.*, 4 (1 & 2): 19-25.

Hassan, M.M. 1994. Prospects of Eucalypts in Bangladesh. *Bangladesh J. For. Sci.*, 23(1):12-19.

Hassan, M.M. 1995. *Eucalyptus* in Bangladesh. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.) *Eucalyptus in Bangladesh, Proceedings of the National Seminar held at Bangladesh Agricultural Research Council*, Dhaka on April 16.1994, pp 5-14.

Higa, R.C. and Sturion, J.A. 1991. Sprouting evaluation of thirteen *Eucalyptus* species in Uberaba, Minas Gerais. *Boletim-de-Pesquisa-Florestal*, 22-23:79-86.

Hill, K.D. and Johnson, L.A.S. 1995. Systematic studies in the eucalypts 7. A revision of the bloodwoods, genus *Corymbia* (Myrtaceae). *Telopea*, 6(2-3):185-504.

Hillis, W. E. 1967. Polyphenols in the leaves of *Eucalyptus*, A chemotaxonomic survey. II. Sections Renantheroideae and Renantherae. *Phytochemistry*, 6(2): 259-275.

Hillis, W.E. and Brown, A.G. 1984. *Eucalypts for Wood Production*. CSIRO, Australia (Second edition), p. 434.

Holmgren, M. and Pettersson, P. 1995. Evaluation of long-term growth trials of *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* in Laos, South-East Asia: a minor field study. Working Paper International Rural Development Centre, Swedish University of Agricultural Sciences, No. 282, pp 24; ISRN SLU-IRDC-WP-282-SE.

Hoque, A.K.M.F. 1977. Soil erosion in teak plantations. ***In:*** *Proceedings of First Bangladesh National Conference on Forestry*, Dhaka. pp. 80-83.

Hossain, A.B.M.E. and Rahman, M.M. 1994. Rohingya refugee rehabilitation in Bangladesh: some environmental consequences. *Aranya*, 3(3): 4-6.

Hossain, M.K. 1998. Role of plantation forestry in the rehabilitation of degraded and secondary hill forests of Bangladesh. *Proceedings of the IUFRO Inter-Divisional Seoul Conference on Forest Ecosystem and Land Use in Mountain Areas*, 12-17 October, 1998, Seoul, Korea, pp. 243-250.

Hossain, M.K. 2008. The contribution and critics of exotic species in the plantation forestry of Bangladesh. ***In:*** S.K. Chauhan, S.C. Sharma, R. Chauhan and S.S. Gill (eds.), *Exotics in Indian Forestry*, Agrotech Publishing Academy, Udaipur-313 001. pp. 324-335.

Hossain, M.K. 2010. *Casuarina equisetifolia* - a promising species for green belt project of coastal and off-shore islands of Bangladesh. In: Imptroving small holder livelihoods through improved Casuarina productivity: Proceedings of the fourth International Casuarina workshop, Haikou, China. 20-25 March 2010. C. Zhong, K. Pinyopusaresk, A. Kalingarire and C. Franche (eds.), pp. 200-206.

Hossain, M.K., Islam, Q.N., Islam, S.A., Tarafdar, M.A., Zashimuddin, M. and Ahmed, M. 1989. *Status Report on the Activities of the Silvicultural Research Division*, Assistance to the Second Agricultural Research Project, Bangladesh. BFRI, FAO, Chittagong, p. 20.

Hossain, M.K., Zashimuddin, M., Islam, S.A., Tarafdar, M.A. and Islam, Q.N. 1994. Growth and yield of coppice crops of three *Eucalyptus* species in the sal forests of Bangladesh. *Bangladesh Journal of Forest Sciences,* 23(2): 61-66.

Hossain, M.K., Hossain, M.S. and Islam, Q.N. 1995. Selection of plantation tree species for degraded sal forest areas of Bangladesh. *Bangladesh Journal of Forest Sciences*, 24(2): 5-10.

Hossain, M.K., Zashimuddin, M., Tarafdar, M.A., Islam, S.A. and Islam, Q.N. 1996a. Seven year growth and biomass production of *Eucalyptus brassiana* provenances at Tangail, Bangladesh. *Bangladesh Journal of Forest Science*, 25(1&2):43-48.

Hossain, M.K., Sarker, S, and Kamaluddin, M. 1996b. Initial growth performance of 12 provenances of four *Eucalyptus* species at Chittagong University Campus. *Chittagong Univ. Stud.,* Part II : Sci., 20(1): 129-131.

Hossain, M.K., Islam, S.A., Zashimuddin, M., Tarafdar, M.A. and Islam, Q.N. 1997. Growth and biomass production of some *Acacia* and *Eucalyptus* species in degenerated sal forest areas of Bangladesh. *The Indian Forester,* 123(3):211-217.

Hossain, M.K., Hossain, M.S. and Aryal, U.K. 1998. Initial growth performance of eight provenances of *Acacia auriculiformis* at Chittagong University campus, Bangladesh. *The Indian Forester*, 124(4): 256-258.

Hossain, M.K., Hossain, M.S., Muhammad, N. 1998. A comparative study of undergrowth of *Eucalyptus camaldulesis* and some other plantation in sal forest areas of Bangladesh. *Indian Journal of Forestry*, 21(2): 93-96.

Hossain, M.K., Dhali, M.A.H. and Hossain, M.S. 2002. Effects of forest soil and leaf-litter on germination and initial seedling growth of *Leucaena leucocephala*. *Allelopathy Journal*, 10(1):13-20.

Hossain, M.K. and Pasha, M.K. 2004. An account of the exotic flora of Bangladesh. *Journal of Forestry & Environment*, 2:99-115.

Hossain, M.K. and Khan, B.M. 2005. Growth performance of multipurpose tree species in the degraded hill areas of Bangladesh. ***In:*** V.P. Tewari, (ed.), *Multipurpose Tree in the Tropics: Management and Improvement Strategies.* Arid Forest Research Institute, Jodhpur, India. pp. 64-70.

Hubble, G.D., Isbell, R.F. and Northeote, K.H. 1983. Features of Australilan soils, ***In:*** *Soils: an Australian Viewpoint,* Commonwealth Scientific & Industrial Research Organization, Melbourne, 17.

Hughes, C.E. 1994. Risks of species introductions in tropical forestry. *Comm. For. Rev.*, 73(4):243-252.

Hummel, F.C. 1989. Utilization strategies for forest biomass from short rotation tree plantations. In: J.S. Pereira and J.J. Landsberg (eds.), *Biomass production by fast growing trees*, Kluwer Academic Publishers, Dordrecht/Boston/London, pp. 275-280.

Huong, N.S. 1993. Propagation of *Eucalyptus urophylla*. Forest Research Newsletter *Bai Bang.*, 4: 1-2.

Igboanugo, A.B.I. 1986. Phytotoxic effects of *Ecualyptus* on food crops, particularly on germination and radicle extension. *Trop. Sci.*, 2: 419-24.

Igboanugo, A.B.I. 1987. Effect of *Eucalyptus* on growth and yield of *Amaranthus caudatus and Abelmoschus esculentus. Agri. Ecosys. Environ., 18: 243-50.*

Igboanugo, A.B.I. 1988. Effect of *Eucalyptus* on yield of *Vigna unguiculata L.* Walp., *Zea mays* L. and *Sorghum bicolor. Agric. Ecosys. Environ.*, 24: 453-58.

Islam, A.K.M.N. 1991. *Two centuries of plant studies in Bangladesh and adjacent regions.* Asiatic Society of Bangladesh, Dhaka.

Islam, Q.N., Islam, S.A., Tarafdar, M.A. and Hossain, M.K. 1997. Growth and biomass estimation of *Eucalyptus urophylla* provenance trial in degenerated sal forest areas of Bangladesh. *Indian Journal Forestry*, 20(1): 78-81.

Jacobs, M.R. 1955. *Growth habits of the Eucalypts*. Commonwealth Forestry and Timber Bureau, Canberra, Australia: Government Printer, p. 262.

Jacobs, M.R. 1981. Eucalypts for planting. ed. 2. Forestry Series No. 11. Rome: FAO, pp. 677.

Jambhale, N.D. and Patil, S.C. 1996. Micropropagation of elite *Eucalyptus* types through shoot tip culture. *Indian Forester*, 122(1):61-64.

Kabir, M.F., Bhattacharjee, D.K. and Sattar, M.A. 1995. Strength properties of drying characteristics of *Eucalyptus* wood grown in Bangladesh. *Thai Journal of Forest*, 14: 103-109.

Kanowski, P.J. and Savill, P.S. 1992. Forest plantations: towards sustainable practice. ***In:*** C. Sargent and S. Bass (eds.), *Plantation Politics: Forest Plantations in Development.* Earthscan, London, p. 121-151.

Karanth, U. and Singh, M. 1983. *What People say about Eucalyptus? – Breaking up the wrong tree.* Leaflet of the Forest Research Institute and Colleges, Dehra Dun, p. 8.

Karim, A.B. and Savill, P.S. 1991. Effect of spacing on growth and biomass yield production of *Gliricidia sepium* (Jack) Walp. in an alley cropping system in Sierra Leone. *Agroforestry Systems*, 16:213-222.

Karschon, R. and Heth, D. 1967. The water balance of a plantation of *Eucalyptus camaldulensis* Dehn. *Contributions on Eucalyptus in Israel*, III : 7-34.

Keating, W.G. and Bolza, E. 1982. *Characteristics, Properties and Uses of Timbers*. Volume 1. South-east Asia, Northern Australia and the Pacific. Inkata Press, Melbourne, p. 362.

Kerkhoff, E. and Sharma, E. 2006. *Debating Shifting Cultivation in the Eastern Himalayas-Farmers innovations as lessons for Policy*, ICIMOD, Kathmundu, Nepal, p. 92.

Khan, M.S. and Alam, M.K. 1996. Homestead Flora of Bangladesh. Bangladesh Agricultural Research Council, Dhaka, p. 275.

Khan, N.A., Choudhury, J.K., Huda, K.S. and Mondal, M.I. 2004. *An Overview of Social Forestry in Bangladesh*. Forestry Sector Project, Bangladesh Forest Department, p. 198.

Kibria, M.G., Hossain, A.T.M., Sarker, D.C., Hoque, M.M. and Mannan, M.A. 1999. Financial analysis of *Eucalyptus camaldulensis* plantations in Bangladesh. *Bangladesh Journal of Forest Science*, 28 (2):102-108.

King, K.F.S. 1979. Agroforestry and the utilization of fragile ecosystems. *Forest Ecol. Management,* 2: 161-168.

Kohli, R.K. 1990. *Allelopathic properties of Eucalyptus*. Project Report MAB DoEn Project, p. 199.

Kohli, R.K. and Singh, D. 1991. Allelopathic impacts of volatile components from *Eucalyptus* on plants. *Biol. Plant*, 33: 475-83.

Kohli, R.K., Singh, D. and Verna, R.C.1990. Influence of *Eucalyptus* shelterbelt on winter season agroecosystems. *Agric. Ecosys. Environ.*, 33: 23-31.

Kulkarni, H.D. and Lal, P. 1995. Performance of *Eucalyptus* clones at ITC Bhadrachlam, India. ***In:*** B.M. Potts, N.M.G. Borralho, J.B. Reid, R.N. Cromer, W.N. Tibbits and C.A. Raymond (eds.) *'Eucalypt plantations: Improving fiber yield and quality' Proceedings of the Co-operative Research Centre for Temperate Hardwood Forestry Conference*, Hobart, 19-24/2/1995, Co-operative Research Centre for Temperate Hardwood Forestry: Hobart, pp 336-338.

Lange, R.T. and Reynolds, T. 1981. Halo-effects in native vegetation, *Trans. R. Soc. South Aust.,* 105: 213.

Langkamp, P.J. 1987. *Germination of Australian Native Plant Seed*. Inkata Press, Melbourne, pp. 46-57.

Latif, M.A. 1985. Effect of different levels of fertilization on the growth of *Eucalyptus camaldulensis* in the depleted hill soils of Bangladesh. *Proc. of IUFRO Conf. Inventory and Monitoring Endangered Forests*. Zurich, August 19-24, pp. 81-82.

Latif, M.A. 1988. Biomass tables for young *Eucalyptus* grown in Bangladesh. *Bano Biggyan Patrika,* 17 (1&2): 46-54.

Latif, M.A., Das S. and Rahman, M.F. 1983. Growth and yield of *Eucalyptus camaldulensis* in Bangladesh. *Proceedings from the IUFRO Conference* held in Copenhagen 14-17 June 1993.

Latif, M.A., Zashimuddin, M., Hossain, M.K., Islam, S.A. and Davidson, J. 1985. Coppice production from three Eucalypt species. ***In:*** J. Davidson and S. Das (eds.), *Eucalypts in Bangladesh - a Review*. Silviculture Division Bulletin No. 6. Bangladesh Forest Research Institute, Chittagong, Bangladesh, pp. 117-134.

Latif, M.A., Wahab, M.A. and Islam, M.J. 1985a. The relationship between crown diameter and diameter at breast height of *Eucalyptus citriodora*. Bulletin No. 6, Silviculture Res. Division BFRI, Chittagong, pp. 241-242.

Latif, M.A., Wahab, M.A. and Islam, M.J. 1985b. The relationship between height and diameter for *Eucalyptus citriodora.* Bulletin No. 6, Silviculture Res. Division, Bangladesh Forest Research Institute, Chittagong, pp. 243-246.

Latif, M. A., Islam, M. S. and Islam, S. M. Z. 1999. *Volume tables for sissoo, koroi, mahogany, eucalypts and bokain planted on croplands in the north and western parts of Bangladesh* (Mimeograph). Village and Farm Forestry Program, Swiss Agency for Development and Cooperation, Dhaka, Bangladesh.

Latif, M.A. and Islam, S. M. Z. 2004. *Timber and fuelwood volume tables for Acacia auriculiformis, A. mangium, Eucalyptus camaldulensis and Dalbergia sissoo in plantations in Bangladesh* (Mimeograph). A joint work of Forestry Sector Project, Bangladesh, Forest Department and BFRI, Chittagong, p. 38.

Le Roux, J.J. and Staden, J.V. 1991. Micropropagation and tissue culture of *Eucalyptus*- a review. *Tree Physiology*, 9: 435-477.

Lima, W. de P. 1984. The hydrology of eucalypt forests in Australia - A review. *IPEF, Piracicaba,* 28:11-32.

Lima, W. de P. 1987. O reforestamento com eucalypto e seus impactos ambientais. [*Reforestation With the Eucalypt and its Environmental Impacts*] Sao Paolo, Brazil, Art press, p. 114.

Little, E.L. 1983. *Common Fuelwood Crops.* Morgantown, West Virginia. Communi-Tech Associates, p. 354.

Lovett, J.V. 1985. Defensive stratagems of plants, with special reference to allelopathy. *Papers Proc. R. Soc. Tasmania,* 119: 31.

Lovett, J.V., Ryuntyn, M.Y. and Liu, D.L. 1989. Allelopathy, chemical communication, and plant defense. *J. Chem. Ecol.*, 15: 1193-1202.

Luna, R.K. 1996. *Plantation Trees.* International Book Distributors, Dehra Dun-248001, India, p 975.

Manzoor-I-Khuda, M., Rahman, M., Yusuf, M., Chowdhury, J. and Wahab, M.A. 1987. Studies on essential oil bearing plants of Bangladesh. Part 3 – Essential oil of *Eucalyptus camaldulensis* leaves. *Bang. J. Sci. Ind. Res.*, 22 (1-4): 152-161.

Marcar, N.E., Crawford, D.F., Leppert, P.L., Jovanovic, T., Floyd, R. and Farrow, R. 1995. Trees for salt land: a guide to selecting native species for Australia. Melbourne, Australia: CSIRO, p. 72.

Marien, J.N. 1991. Clonal forestry in Morocco: propagation and maturation problems. ***In:*** A.P.G. Schonau (ed.), *Proceedings IUFRO Symposium on Intensive Forestry: The Role of Eucalypts*. Vol. 1. South African Forest Research Institute, pp. 126-132.

May, F.E. and Ash, J.E. 1990. An assessment of the allelopathic potential of *Eucalyptus. Austr. J. Bot.*, 38: 245–254.

Metro, A. 1955. *Eucalypts for planting.* FAO Forestry and Forest Product Studies No. 11, Rome, p. 236.

Midgley, S.J., Eldridge, K.G. and Doran, J.C. 1989. Genetic resources of *Eucalyptus camaldulensis*. *Commonwealth Forestry Review*, 68(4):295-308.

Millat-e-Mostafa. 1997. Floristics and indigenous management techniques of homegardens in Bangladesh. ***In:*** M.K. Alam, F.U. Ahmed and S.M.R. Amin (eds.), *Agroforestry: Bangladesh Perspective*. APAN, NAWG and BARC, Dhaka, Bangladesh, pp. 34-63.

Motaleb, M.A. and Irfanullah, H.M. 2011, Tobacco cultivation in Bangladesh: is it a threat to traditional agro-practic? Ind. J. Traditional Knowledge, 10(3):481-485.

Movsumov, I.S. and Aliev, A.M. 1985. Tri-terpenenoids acids from some *Eucalyptus* specimens. *Khim Prir. Soedin.*, 2: 271-272.

Muller, W.H. and Muller, C.H. 1964. Volatile growth inhibitors produced by *Salvia* species. *Bull. Torrey Bot. Club*, 91: 327-330.

Munshi, A.I. 1986. The red gums and their potential in Bangladesh. Assistance to the Forestry Sector of Bangladesh, UNDP/FAO Project BGD/79/017. Occasional Paper No. 4, p. 171.

Nambiar, E.K.S. 1996. Sustained productivity of plantation forests is a continuing challenge to tree improvement. ***In:*** M.J. Dieters, D.G. Matheson, C.E. Harwood and S.M. Walker (eds.) *Tree improvement for sustainable tropical forestry*. Proceedings QFRI-IUFRO Conference, Caloundra, Queensland, Australia 27 October - 1 November 1996, 6-18. Queensland Forestry Research Institute, Gympie.

NRC (National Research Council). 1983. *Firewood Crops*. Vol. 2. Washington D.C., National Academy Press, p. 92.

Nghia, N.H. 1996. Climatic requirements of some main plantation tree species in Vietnam. ***In:*** T.H. Booth (ed.), *Matching Trees and Sites*. ACIAR Proceedings No. 63: 43-49.

Onyewotu, L.O.Z. and Stigter, C.J. 1995. *Eucalyptus* - its reputation and its roots: millet and a *Eucalyptus* shelterbelt in northern Nigeria. *Agroforestry Today*, 7(1):6-8.

Osman K.T., Haque S.M.S. and Mia, F. 1992a. Aboveground biomass and nutrient distribution in *Acacia auriculiformis*, *Dipterocarpus turbinatus* and *Pinus caribaea* plantations at Chittagong University hills. *Indian Journal of Forestry*, 15 (3): 193-197.

Osman K.T., Islam, M.S. and Haque S.M.S. 1992b. Performance of some fast growing trees in the University of Chittagong campus. *The Indian Forester*, 118 (II): 858-859.

Ovington, J.D. and Pryor, L.D. 1983. Temperate broad-leaved evergreen forests of Australia. ***In:*** J.D. Ovington (ed.) *Temperate Broad-leaved Evergreen Forests*. Ecosystems of the World II. Amsterdam, Elsevier, pp. 73-103.

Pattnaik, S., Subramanyam, V.R. and Kole. C. 1996. Antibacterial and antifungal activity of ten essential oils in vitro. *Microbios*, 86 (349): 237-246.

Paul, S.P. and Ahmed, T. 1995. Response of different N, P and K level on the growth of *Eucalyptus camaldulensis* seedlings. ***In:*** *Proc. of Inter- congress Conference of Commission IV on Improving soil management for intensive cropping in the tropics and subtropics*, held in 1-3 December 1992, ISSS/BARC/SSSB, Dhaka, Bangladesh, pp. 35-38.

Paul, S.P., Hossain, A.T.M.E. and De, H.B. 1998. Growth response of *Eucalyptus camaldulensis* to different fertilizer in one year old plantation. *Bang. Jour. of For. Sci.*, 27(2):128-132.

Pegg, R.E., Wang, G.X. and Brown, A.G. 1994. Results of *Eucalyptus pellita* [provenance] trials at Dongmen, [Guangxi] China. *Australian tree species research in China*: Proceedings of an International Workshop held at Zhangzhou, Fujian Province, PRC, 2- 5 November 1992, pp. 108-115.

Penfold, A.R. and Willis, J.L. 1961. The Eucalypts. Botany, cultivation, chemistry, and utilization. Leonard Hill [Books] Limited, London; Interscience Publishers, Inc., New York, p. 551.

Pereira, J.S, Linder, S., Araujo, M.C., Pereira, H., Ericsson, T., Borralho, N. and Leal, L.C. 1989. Optimization of biomass production in *Eucalyptus globulus* plantations- A case study. *In:* J.S. Pereira and J.J. Landsberg (eds.), *Biomass Production by Fast growing Trees*, Kluwer Academic Publishers, Dordrecht/Boston/London. pp. 101-121.

Poore, M.E.D. and Fries, C. 1985. *The Ecological Effects of Eucalyptus*, FAO Forestry Paper No.59, Rome, p. 88.

Poynton, R.J. 1979. *Tree Planting in Southern Africa*. Vol. 2. The Eucalypts. Pretoria, South Africa: Dept of Forestry.

Prabhakar, V.K. 1998. *Social and Community Forestry*. Satish Garg, New Delhi, pp. 90-106.

Prado, J.A. and Barros, S. 1989. *Eucalyptus, principios de silvicultura y manejo*. Instituto Forestal, Santiago de Chile.

Prescott, E.E. 1941.Germination of the seeds of mallee eucalypts, *Victorian Nat.,* 58, 8.

Prescott, J.A. and Poper, C.S. 1932. The soils of the South Australian mallee, *Trans. R. Soc. South Aust.,* 56, 118.

Prober, S.M. 1992. Environmental influences on the distribution of the rare *Eucalyptus paliformis* and the common *E. fraxinoides, Aust. J. Ecol.*, 17: 51.

Pryor, L.D. 1976. *The biology of Eucalypts*. Institute of Biology's Studies in Biology No. 61, p. 82.

Pryor, L.D. and Johnson, L.A.S. 1971. *A classification of the eucalypts*. Canberra, Australia: Australian National University, p. 102.

Pryor, L.D. and Johnson, L.A.S. 1981. *Eucalyptus*, the Universal Australian. ***In:*** A. Keast (ed.), *Ecological Biogeography of Australia, Vol. 1*. The Hague, Junk, pp. 499-536.

Qadri, S.M.A. 1983. Monographs on *Eucalyptus camaldulensis, E. microtheca, E. tereticornis*. Karachi, Pakistan, p. 106.

Rao, N.S. and Reddy, P.C. 1984. Studies on inhibitory effect of *Eucalyptus* (hybrid) leaf extracts on the germination of certain food crops. *Indian Forester*, 110 (2):218-222.

Rashid, H.E. 1991. *Geography of Bangladesh*. University Press limited, Dhaka.

Rashid, M.H. 1969. Trial cultivation of *Eucalyptus* in East Pakistan. *Forestdale News.*, 2(4): 39-44.

Raymond, C.A. 1991. *Eucalyptus camaldulensis* - a breeding plan for Thailand, ACIAR Project 8808. Canberra, Australia: Australian Centre for International Agricultural Research.

Reid, R. and Wilson, G. 1985. *Agroforestry in Australia and New Zealand,* Goddard & Dobson, Box Hill, Victoria, 223.

Richardson, S.D. 1990. Forests and Forestry in China: Changing patterns of resource development, Washington D.C., Inland press, p. 374.

Rotheram, I.R. 1983. Suppression of growth of surrounding regeneration by veteran trees of karri (*Eucalyptus diversicolor*), *Aust. For.*, 46: 8.

Roy, R.D. 1997. The population transfer program of 1980s and the land rights of the indigenous peoples of Chittagong Hill Tracts. ***In:*** Bhaumic et al., (Eds.) *Living on the Edge: essays on the Chittagong Hill Tracts.* South Asian Forum for Human Rights, Kathmandu, pp. 167-208.

Salam, M.A., Noguchi, T. and Koike, M. 1999. The causes of forest cover loss in the hill forests in Bangladesh. *Geojournal*, 47:539-549.

Sattar, M.A. and Bhattacharjee, D.K. 1990. *Physical and Mechanical Properties of Eucalyptus camaldulensis.* Bulletin 12, Timber Physics Series, Bangladesh Forest Research Institute, Chittagong, p. 8.

Sattar, M.A. 1995. Potentiality of utilization of *Eucalyptus* in Bangladesh. ***In:*** S.M.R. Amin, M.O. Ali and M.I.M. Fattah (eds.) *Eucalyptus in Bangladesh, Proceedings of the National Seminar held at Bangladesh Agricultural Research Council*, Dhaka on April 16.1994, pp 27-33.

Saxena, N.C. 1994. *India's Eucalyptus Craze: The God that Failed.* Sage Publications, New Delhi.

Seth, S.K., Bakshi, B.K., Reddy, M.A.R. and Sujan Singh. 1978. Pink disease of *Eucalyptus* in India. *European Journal of Forest Pathology*, 8(4):200-216.

Sharma, J.K., Mohanan, C. and Florence, E.J.M. 1985. *Disease survey in nurseries and plantations of forest tree species grown in Kerala.* KFRI Research Report, Kerala Forest Research Institute, No. 36.

Sharma, J.K., Nair, C.T.S., Kedharnath, S. and Kondas, S. (eds.). 1984. *Eucalypts in India - Past, Present and Future.* Proceedings of a National Seminar, January 1984, Peechi, Kerala Forest Research Institute.

Sheikh, M.I. 1981. *Management study of Eucalyptus camaldulensis.* Final Technical Report, January 1975 to June 1981. Peshawar, Pakistan: Pakistan Forest Institute.

Shiva, M.P., Rubab, J. and Jaffer, R. 1990. Prospects by models for raising aromatic plants in different forestry programmes for economic uplift. *Indian Forester*, 116(2):168-176.

Shiva, V. and Bandyopadhyay, J. 1983. *Eucalyptus*- A Disastrous Tree in India. *The Ecologist*, 13(5): 184187.

Siddiqi, N.A. 2001. *Mangrove Forestry in Bangladesh*. Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh, p. 201.

Singh, D. and Kohli, R.K. 1992. Reasons of poor under floor vegetation of *Eucalyptus*. ***In:*** P. Tauro and S.S. Narwal (eds.), *Proceedings First National Symposium on Allelopathy in Agroecosystems*. Hisar, India: Indian Society of Allelopathy, pp. 114-117.

Singh, R. and Bawa, R. 1982. Effect of leaf-leachates from *Eucalyptus globulus* Labill and *Aesculus indica* Coleber. on germination of *Glaucium flavum* Crantz. *Ind. J. Ecol.*, 9: 21-28.

Singh, B. and Sinha, G.K. 1981. Chemical study of the essential oil of *Eucalyptus camaldulensis* in trial regions of Kumaon (Uttar Pradesh), *PAFAI J.*, 3 (1): 20-21.

Singhal, K.M., Banerjee, S.P. and Pathak, I.C. 1975. Effect of *Eucalyptus* monoculture on the status of soil organic matter in natural Sal (*Shorea robusta*) forests. *Indian Forester*, 101 (12): 730-737.

Soerianegara, I. and Lemmens, R.H.M.J. (eds.) 1993. Plant resources of South-East Asia (PROSEA) 5(1). *Timber trees: Major commercial timbers*. Pudoc, Wageningen, NL.

Srivastava R.J., Kumar A. and Prasad K. 2003. Studies on soil moisture variations under *Eucalyptus* plantation. *Paper presented in the XII World Forestry Congress*, held from 21 to 28 September 2003 in Québec, Canada. Accessed via net http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0500-B2.HTM

Stocker, G.C. 1969. Fertility differences between the surface soils of monsoon and eucalypt forests in the Northern Territory, *Aust. For. Res.*, 4, 31.

Story, R. 1967. Pasture patterns and associated soil water in partially cleared woodland. *Aust. J. Bot.*, 15, 175.

Streets, R.J. 1962. *Exotic forest trees in the British Commonwealth*. Oxford, UK: Clarendon Press.

Sun, D. and Dickinson, G.R. 1995. Survival and growth responses of a number of Australian tree species planted on a saline site in tropical north Australia. *Journal of Applied Ecology*, 32(4):817-826.

Tewari, D.N. 1992. *Monograph on Eucalyptus*. Dehra Dun, India; Surya Publications, pp. 361.

Tiwari, K.M. and Mathur, R.S. 1983. Water consumption and nutrient uptake by *Eucalyptus*. *Indian Forester*, 109 (12): 851-860.

Trigg, J.K. 1996a. Evaluation of *Eucalyptus*-based repellent against *Anopheles* spp. in Tanzania. *Journal of the American Mosquito Control Association*, 12 (2, Part 1): 243-246.

Trigg, J.K. 1996b. Evaluation of *Eucalyptus*-based repellent against *Culicoides impunctatus* (Diptera: Ceratopogonidae) in Scotland. *Journal of the American Mosquito Control Association*, 12 (2, Part 1): 329-330.

Turnbull, J. W. and Brooker, I. 1978. Timor mountains gum. *Eucalyptus urophylla* S.T. Blake. Forest Tree Series, Division of Forest Research, CSIRO, Australia, No. 214, p. 4.

Turnbull, J.W. (ed.) 1986. *Multipurpose Australian Trees and Shrubs. Lesser-known Species for Fuelwood and Agroforestry*. ACIAR Monograph No. 1, p. 316.

Turnbull, J.W. 1981. *Eucalyptus* in China. *Australian Forestry*, 44(4):222-234.

Turnbull, J.W. and Doran, J.C. 1987. Seed development and germination in the Myrtaceae. ***In:*** P.J. Langkamp, (ed.), *Germination of Australia native plant seed*. Melbourne, Australia: Inkata Press: 46-57; 186-198.

Turnbull, J.W. and Pryor, L.D. 1984. Choice of species and seed sources. ***In:*** W.E. Hillis and A.G. Brown (eds.), *Eucalypts for Wood Production*. Sydney, Australia: CSIRO, Australia and Academic Press, pp. 6-65.

Turvey, N.D. 1996. Growth at age 30 months of *Acacia* and *Eucalyptus* species planted in *Imperata* grasslands in Kalimantan Selatan, Indonesia. *Forest Ecology and Management*, 82(1-3):185-195.

Uddin, M.B., Ahmed, R. and Hossain, M.K. 2000. Allelopathic potential of water extracts of *Leucaena leucocephala* leaf on some agricultural crops in Bangladesh. *The Chittagong University Journal of Science*, 24(1): 121-127.

Uddin, M. K. 1996. *Clonal propagation of Eucalyptus and Acacia hybrid by stem cuttings*. Bangladesh Agricultual Research Council (BARC), Winrock International Institute for Agricultural Development (WI) and International Development Research Centre (IDRC). p. 31.

van Steenis, C.G.G.J. 1971. *Nothofagus*, Key genus of plant geography in time and space, living and fossil, ecology and phylogeny, *Blumea*, 19, 65.

Vats, R., Nandal, S.N. and Dalal, M.R. 1996. Comparative efficacy of different preparations of leaf extracts of *Azadirachta indica* and *Eucalyptus tereticornis* against *Meloidogyne javanica* in tomato nursery. *Haryana Agricultural University Journal of Research*, 26(2): 99-102.

Verma, S.K. and Bagchi, S.K. 1997. Effect of substrates on the rooting response of *Eucalyptus tereticornis* juvenile cuttings. *Indian Forester*, 123(2):153-156.

Vozzo, J.A. (ed.). 2002. Tropical Tree Seed Manual. USDA Forest Service, p. 899.

Weiss, E.A. 1997. *Essential Oil Crops*. Wallingford, UK: CAB International.

White, K.J. 1979. Fast-growing tree species for industrial plantations, *Eucalyptus*, *Pinus* and others. Field document No. 18, BFRI, Chittagong, p. 90.

White, K.J. 1988. *Eucalyptus* on small farms. ***In:*** D. Withington, K.G. Macdicken, C.B. Sastry, and N.R. Adams (eds.) *Multipurpose Tree Species for Small Farm Use*. Arlington, Virginia, USA, Winrock International Institute for Agricultural Development and International Development Research Centre, Canada, pp. 86-96.

White, K.J. 1986. *Practical tree breeding strategies and practices and programmes in the Bhabar Terai of central Nepal*. Manual Sagarnath Forest Development *Project*, Ministry of Forests, Nepal, No. 5, p. 47.

Wilcox, M.D. 1997. A Catalogue of the Eucalypts. Auckland, New Zealand: Groome Pöyry Ltd.

Willis, R.J. 1991. Research on allelopathy on *Eucalyptus* in India and Pakistan. *Commonwealth For. Rev.*, 70: 4.

Withers, J.R. 1978. Studies on the status of unburnt *Eucalyptus* woodland at Ocean Grove, Victoria. II. The differential seedling establishment of *Eucalyptus ovata* Labill. and *Casuarina littorali. Aust. J. Bot.,* 26, 465.

World Bank. 1997. *Review of the Key Environmental Issues in Bangladesh*, Workshop Discussion Draft (May 1997), World Bank, Dhaka, p. 22.

Wrigley, T.J. and Cowan, M. 1995. Octanol partition coefficients for wetland humus. *Water Res.*, 29:11.

Xiang, D., Wang, G. and Pegg, R.E. 1996. Value of selection in *Eucalyptus tereticornis* at Dongmen, People's Republic of China. ***In:*** M.J. Dieters, A.C. Matheson, D.G. Nikles, C.E. Harwood, and S.M. Walker (eds.). *Tree Improvement for Sustainable Tropical Forestry*. Proceedings QFRI-IUFRO Conference, Caloundra, Queensland Australia, 27 October-1 November (Gympie: Queensland Forestry Research Institute), pp. 355-360.

Yasid, M.S., Lee, S.S., Lapeyreee, E. 1996. Mycorrhizal inoculation of *Hopea odorata* (Dipterocarpaceae) in the nursery. *Journal of Tropical Forest Science*, 9(2): 276–278.

Younus-uzzaman, M. and Akhter, K. 1999. Pressure treatment of *Eucalyptus camaldulensis* poles with oil bore preservative. *Bang. Jour. For. Sc.*, 28 (1):47-53.

Zacharin, R.F. 1978. *Emigrant eucalypts: gum trees as exotics*. Melbourne, Australia; Melbourne University Press, p. 137.

Zackrisson, O. and Nilsson, M.C. 1992. Allelopathic effects by *Empetrum hermaphroditum* on seed germination of two boreal tree species. Can. J. For. Res., 22: 44-56.

Zashimuddin, M., Hossain, M.K., Tarafdar, M.A. and Latif, M.A. 1985. Provenance trials of *Eucalyptus* established in 1983. ***In:*** J. Davidson and S. Das (eds.), 1985. *Eucalypts in Bangladesh - a Review.* Silviculture Division Bulletin No. 6. Chittagong, Bangladesh. Bangladesh Forest Research Institute, pp 105-116.

Zashimuddin, M., Latif, M.A., Khan, S.A. and Davidson, J. 1983. Performance of different provicences of *Acacia mangium* in Bangladesh. *Bano Biggyan Patrika*, 12(1&2): 57-61.

Zhong, C. and Bai, J. 1997. Advances in improvement research of *Eucalyptus* in China. IUFRO Conference on Silviculture and Improvement of Eucalypt, 1997, Salvador. *Proceedings. Vol. 1. Tree improvement strategies.* Colombo: EMBRAPA, pp. 64-67.

Zira, S. and Benjilali, B. 1991. Effect of drying on leaf oil production of Moroccan *Eucalyptus camaldulensis, J. Esent. Oil Res.*, 3 (2):117-18.

Zohar, Y. 1989. Biomass production of short rotation *Eucalyptus camaldulensis* Dehn. stands growing on peat soil under a high water table in Israel. *South African Forestry Journal*, 149:54-57.

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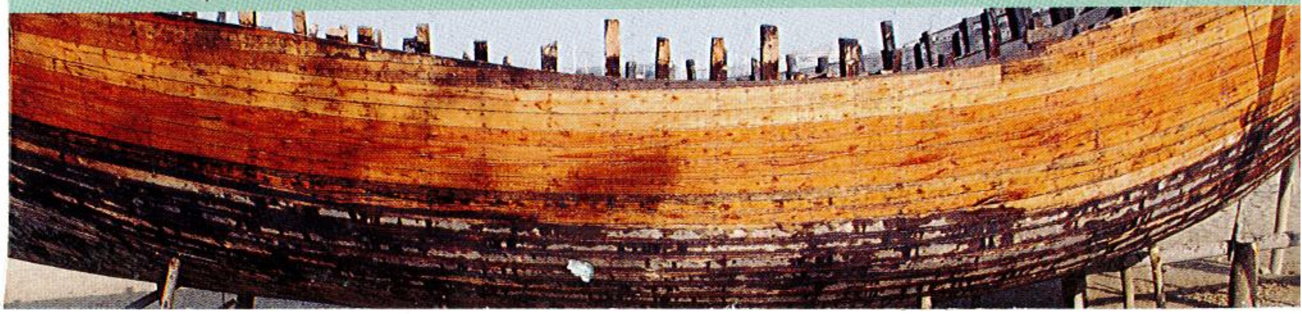

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