PROVENANCE VARIATION AND PROGENY TESTING OF
Eucalyptus urophylla S.T. Blake GROWN AT LAD KRATING PLANTATION, CHACHOENGSAO PROVINCE

INTRODUCTION

Population and economic growth has exerted great pressure on land and forest resources in Thailand. Programs aimed at increasing food production and alleviating population pressure have contributed to forest clearance, opening up of new lands, soil erosion, reduced soil fertility, and wildlife habitats. Recent figures indicated that Thailand's 51,089,000 hectares of total land area has 28.9% (14,764,721 hectares) of total forest cover, which was improved with the expansion of plantations, tree farms and natural restoration activity. Of these 4,920,000 hectares or 9.6% of forest land area are in plantations. These forests still have an important role of providing wood needs in the country. For example, the main production and consumption of wood products in Thailand during the past year was fuelwood, which was 62% or 20,250,000m^3 of the total wood consumption (FAO, 2005).

Thailand's earliest forest plantation was established under the Taungya System at Mae Pange, Denchai, with planting of teak in Prae province, Northern Thailand. Plantation with other species than teak was carried out in 1919 at Ban Lam, Petchburi province (RFD, 1973). However, concerted efforts in plantation forestry only began in earnest with the establishment of the DANIDA supported Teak Improvement Centre and Pine Improvement Centre in 1965 and 1969 respectively. Following the booming pulp and paper industry in the 1980s, fast-growing exotic species, *Eucalyptus* and *Acacia* were introduced for trials. Privately-owned plantations started to plant fast-growing exotics to supply chipwood to the wood industry and export market due to the high prices and demand (Kijkar, 2000).

The expansion of forest plantations is gradually taking place to compensate the timber volume from natural forests. The development of forest plantation here was brought about by several events. It started with the infamous imposed 1989 logging ban, in addition to the high cost and insecure log supply from neighboring countries, and the currency fluctuation that were all unfavorable events for the various local wood-dependent industries. However, the supply from forest plantations is still largely insufficient, prompting the creation of the contract tree farming systems by the wood industries, as described in detail by Makarabirom (1997). According to Bhumibhamon (1986), Thailand selected 72 native species and 27 exotic species for plantation establishment. Exotic eucalypts have proven very successful in some parts of the country.

Tremendous expansion in the use of eucalypts in plantations of the warm, temperate, and monsoon tropical regions has taken places in the past decades. With more than 800 species (Brooker *et al.*, 2002), the genus *Eucalyptus* are amongst the most domesticated of the major forest plantation species, despite such a brief history

of informed domestication (Kanowski, 1996). Efforts of sustained domestication have been most intensive with those grown for pulpwood production, such as *E. camaldulensis, E. grandis, E. globulus, E. nitens, E. tereticornis* and *E. urophylla* (Timor Mountain Gum), as pure species or in various hybrid combinations, of which the most famous are *E. grandis* x *E. urophylla* and *E. grandis x E. tereticornis* (Eldridge *et al.*, 1993). The eucalypts' popularity as a plantation species can be attributed to their adaptability, fast growth, wide range of utility, environmental and ornamental uses (Poore and Fries, 1985), ability to endure harsh climates and soil conditions, and the absence of leaf-eating insects outside their natural range, which is so much a feature of the natural eucalypt habitat (Pryor, 1978).

Eucalypts have been in use as firewood, poles, shelter and amenity planting for decades. Today, the eucalypts are the most important pulp producing hardwood, used for making paper, rayon and reconstituted wood. In China, eucalypts are imported for essential oils, tannins and growth regulators (phytohormones) production, which offers early returns to establishment investments made by farmers. In Thailand, eucalypt plantings have been found to be more profitable that some conventional cash crops such as cassava and maize, resulting in the involvement of local farmers in the eucalypts nursery business and tree crop farming (Midgley and Pinyopusarerk, 1996). Some eucalypts species has become popular as decorative cut flowers and foliage in Australia and Europe (Sedgley, 1998; Sedgley and Delaporte, 2004).

Eucalypts was first planted in Thailand in Khun Tan, Lampoon, after the first batch of eucalypts seeds were acquired from Australia by the Australian tunnel expert in 1946 (Sa-ardavut, 1981 cited from Lakusta, 1981). Thence, planting expanded to former shifting cultivated areas in Doi Suthep, Chiang Mai. The promotion of eucalypts for tropical climates by FAO, with the endorsement of a study tour to Australia in 1952, activated eucalypts planting in Asia and the Pacific region. As a result, Thirawat (1954) seriously promoted eucalypts growing as there was strong evidence of reasonable growth and adaptation to the climatic and edaphic conditions in Thailand (Chiangmai, Surin, Chumporb). The Thai-Danish Pine Improvement Project in collaboration with RFD, introduced eucalypts seed from Australia for testing in several places in the country. Research on nursery techniques for eucalypts carried out from 1960-1970 had improved successful germination and survival (Kuerkol, 1979 cited from Lakusta, 1981).

An ACIAR-supported project on Australian hardwoods for fuelwood and agroforestry was set us with the co-operation of the RFD, Thailand with the prime objective of field testing (species cum provenance trials) species originating from Australia (Pinyopusarerk, 1989) on several sites in Thailand. This led to a series of tree improvement programs. The energy crisis in 1980, once again emphasized eucalypt planting for fuelwood and charcoal production by the USAID, which initially went well but was under emphasized in later years. The Kandy meeting in 1986 suggested small farmers to grow multipurpose tree species including the following eucalypts; *E. camaldulensis, E. tereticornis, E. urophylla, E. deglupta,* and *E. globulus. Eucalyptus* network was established with most of the coordinating research

facilitation implemented by IUFRO and ACIAR working parties, which collected 31 species for world wide distribution.

Tree improvement is one of the tools available for forest management and should be closely integrated with other research, e.g. on soils and site assessment, on the establishment techniques, on spacing and thinning, and on site assessment. The prerequisite for a tree improvement program is plantation forestry (Willan, 1985b). Lad Krating Plantation large scale establishment of exotic species should have undergone at least species trials to determine the suitable eucalypts species for their area. Provenance variability is evaluated through the provenance trials to aid selection of the best seed sources for plantation establishment. ACIAR has combined species cum provenance trials to shorten the time of breeding program, and the outcome can be used to establish seed production area. The establishment of seed orchards using seeds from the best individuals or clonal material could be supported with progeny testing, which can evaluate the performance of offspring with full- or partially-known identity. With the knowledge from the progeny tests, wild parents with a desired trait could be introduced into a well adapted stock by back-crossing.

Lad Krating Plantation is also testing Timor Mountain Gum in the field through some of the methods mentioned above. Earlier results indicate acceptable growth performances and thus it was introduced into the plantations at various stages. Tree improvement can continue indefinitely, therefore periodic assessment of provenance trials and progeny test is required to give more information to support tree planting activities. Furthermore, it has proven as a productive low-land altitude eucalypts and a useful MPTS.

Objectives

The overall objective of this research aims to improve the genetic material of Timor Mountain Gum for future potential use in large scale plantations.

The specific objectives of this study are as follows:

1. To identify the provenance variation of growth characteristics in Timor Mountain Gum

2. To evaluate the growth characteristics of Timor Mountain Gum progenies

3. To provide genetic material for further tree improvement and breeding programs

LITERATURE REVIEW

Timor Mountain Gum (*Eucalyptus urophylla* S.T. Blake)

The name *Eucalyptus* was coined by the French Botanist, Charles Louis L'Héritier de Brutelle in 1788 (Kantvilas, 1996 cited from Rozefelds, 1996), which refers to the operculate nature of the flower that lacks conspicuous petals and sepals. *Eucalyptus* belongs to the Myrtaceae family, and is characterized by oil glands, epigynous or more rarely perigynous flowers and distinct pollen morphology (Rozefelds, 1996). An epigynous flower has the wall of the receptacle fused to the ovary, and the ovary is inferior, which lies below or is level with the point where the anthers and petals are attached. The perigynous flower has the wall of the receptacles surrounds but not fused to the ovary, and the floral parts rose on the walls of the receptacle. *E. urophylla* is classified under the subgenus *Symphyomyrtus,* section Transversaria. This subgenus is the most commonly planted group of eucalypt species throughout the world (Eldridge *et al.,* 1993).

The species *E. urophylla* is also known as Timor Mountain Gum or Timor White Gum, and in East Timor and Indonesia it is locally known as Popo and Ampupu respectively, and Palavao preto (Portuguese, East Timor). *E. urophylla* has been distinguished as a separate species only recently. Prior to 1977, it has been widely cultivated under the name *E. alba* Reinw. Ex Blume or as *E. decaisneana* Blume. On Java island the name *E. platyphylla* F. Muell. was a synonym of *E. alba*. As a consequence, considerable confusion exists about the true nature of several provenances. Recent morphological analyses supported that specimens from high altitude sites in Timor and from dry sites in Wetar are distinct from *E. urophylla* sensu lato in the Lesser Sunda Islands. These have been designated *E. orophila* L.D. Pryor and *E. wetarensis* L.D. Pryor respectively (Faridah Hanum and Maesen, 1997). These results were comparable with evidence from seedling morphology and oil characteristics (Pryor *et al.,* 2005).

Natural distribution

Timor Mountain Gum is indigenous to Indonesia and to the most recently independent country East-Timor. It is distributed in the south-east, scattered on and around the islands of Timor, Adonora, Alor, Flores, Lomblen and Pantar (Nusa Tenggara region). These islands are situated in a transition region between Australia and Asia known as the Wallace. The species is spread out about 500 km between longitudes 127°E and 122°E, and between latitudes 7°30'S and 10°S (Eldridge *et al.,* 1993; Faridah Hanum and Maesen, 1997).

Habitat and ecology

The Nusa Tenggara Islands are within the wet and dry tropical climatic region. In its natural range the rainfall is monsoonal with 2 to 8 dry months, with a rainfall of 600-2500mm per year. It is found from sea level up to 3000m altitude on volcanic soils in areas with a well-defined dry season. The effects of altitude on mean ambient temperature causes varying temperatures from 27°C-28°C at 400m, and from 17°C-21°C at 1,900m. Mean temperature of the coldest month is 8°C-12°C.

The species is found on mountain slopes and in valleys. Best stand development occurs between 1000-2000m altitude, where mist and fog are common, on favorable sites with moist, deep, well-drained soils generally derived from volcanic and metamorphic rock. Commonly found on basalt, schist and slates but rarely on limestone soils. It tolerates poor soils as long as the texture is loose and prefers soils that remain moist during the dry season. The most notable feature of this species is that it is the sole occupant of a very wide range of altitude and microhabitats. It is usually the dominant species of advance secondary montane forests. At lower altitudes and in drier, exposed locations usually below 1500m, it is often replaced by *E. alba* (Eldridge *et al.,* 1993; Faridah Hanum and Maesen, 1997).

Botanical description

Timor Mountain Gum appears to be one of the most variable of all eucalypts, with considerable variation in morphological features such as adult leaf size and expression of a drip tip, bud characteristics, fruit size and shape. There are also differences between the seedling, juvenile, intermediate and adult leaves. The extreme variation in bark characteristics appears to be associated with differences in available soil moisture and altitude.

This evergreen forest trees are normally 25-45 m tall, diameter up to 1 m diameter, and straight bole for half to two thirds of the tree height. Exceptional specimens can attain 55m in height and diameter up to 2m. In unfavorable environments it is a gnarled shrub.

Timor Mountain Gum typically have decorticating bark, which results in smooth stems often of white or light colored appearance. Bark-shed is seasonal and often related to color change (Pryor, 1976). Bark is variable depending on available moisture and altitude, usually persistent and sub fibrous, smooth to shallowly and closely longitudinally fissured, red brown to pearly-grey, sometimes rough especially at the base of the trunk.

Juvenile leaves are sub-opposite, stalked, broadly lanceolate, 10-15 cm x 5-8 cm, discolourous, lateral veins just visible, at 50° to 70° to the midrib. Adult leaves phyllodinous are sub-opposite to alternate, long stalked (12-30 mm long), broadly lanceolate, abruptly narrowed in a short tip or lanceolate, tapering into a long drip tip,

12-20 cm x 2-5 cm, lateral veins visible at 40° to 50° to the midrib, dark green above, and paler green below.

Inflorescence an axillary, simple umbelliform condensed and reduced dichasium called a conflorescence; umbels solitary, 5-8 flowered; peduncle somewhat flattened, 8-22 mm long; pedicel angled, 4-10 mm long; flowers regular, bisexual; flower buds ellipsoid to obovoid, shortly pointed to rotund, 10-14 mm x 6-10 mm, divided into a calyx tube or hypanthium (lower part) and an operculum (upper part), which is shed at anthesis; stamens numerous, on a staminophore; flowers experience early shedding and occurrence of calyx calyptrate.

The fruit is a typical eucalypt capsule, with a dry thin-walled capsule enclosed in a woody hypanthium, opening with 3-5 included to partly exerted valves, obconical to cup-shaped, 6-14 mm x 7-18 mm; disk almost flat to obliquely depress. It has a double operculum (lid) and the outer operculum is lost early (Eldridge *et al.,* 1993; Soerinegara and Lemmens, 1994; Faridah Hanum and Maesen, 1997).

Silvicultural characteristics

Exploration of Timor Mountain Gum in its natural habitat shows that it is one of the most variable of all eucalypts. On Mt. Mutis of Timor, some very large living trees and stumps up to 2.5 m in diameter were found at an altitude of 2100 m. On cool mountains sites at around 1300m altitude, on deep soils, tall, straight, slender trees occur in often dense forest stands. In drier areas, on shallow soils of the ridges, the habit is different. Trunks are short and thick with many branches forming rounded crowns. The species can grow as a small, gnarled shrub only a few meters or even less than one meter tall at its maximum altitude of 3000m or in peculiar environments.

The appearance of the bark differs according to moisture and altitude. Boles are mainly smooth at lower altitudes and under drier conditions. Below 1000m altitude on Alor and Flores trees have smooth trunks with a short stocking of rough bark at the base. However, between 1000m and 2000m altitude on Timor where conditions are moister and mountain mists occur, the trees are usually covered with rough bark even to the finest branches. Above 2000m altitude in moist conditions the bark is usually sub-fibrous.

The chief characteristics of Timor Mountain Gum are its rapid growth, good form and the ability of some of its provenances to grow well at low altitude. It is planted across the world as short rotation forest. The species grows well where the mean annual rainfall is between 1100-1500mm and have a dry season of 1-5 months. Experiences in Brazil suggests that best growth are likely to be obtained from seed originating between 500-1400m altitude, where the native stands attain best development (Eldridge *et al.,* 1993; Faridah Hanum and Maesen, 1997).

The trees may begin to set flowers when they are 2-3 years old and seeds are produced abundantly within 4 years growth. Flowering occurs during the dry season and 6 months later the seeds mature. The flowers are pollinated by a number of insects, birds, mammals, and to a lesser extent by wind. In Indonesia, the species shows considerable variation in flowering time according to the level of altitude. For instance, between 500-1000m altitudes Timor Mountain Gum flowers during the rainy season, which begins in the middle of May and lasts until the end of July. Flowering occurs at a much slower rate at higher altitudes. Between 1000-2000m the flowering season begins from May until August. Above 2,000m the flowering season only starts in October to November (Alrasjid and Widiarti, 1987).

The breeding system of most *Eucalyptus* may be expressed as one of preferential out-crossing which is supported by a gene-controlled incompatibility mechanism which hinders selfing. The genus is generally protandrous in which anthers dehisce and pollen is shed from each flower before its stigma is receptive. However, inbreeding can still occur as evidence from seed set of isolated trees (Pryor, 1976).

Altitudinal variations are also expressed in the size and abundance of fruits and seeds. Fruits and seeds were small at low altitude and much larger at high altitude. On wet sites in the north-west of East Timor the fruits were the smallest, the trees had narrower leaves, rough bark and good form. On the other hand, on drier sites in the south-west, the trees had 25 times larger volume of fruits, large leaves, smooth bark on the branches and poor stem form (Eldridge *et al.*, 1993).

The seeds are mature when the fruit becomes hard and brown and begins to open. For seed propagation, the fruits should be collected before they open. Fruiting branches are cut and placed in paper or cloth bags. The seeds must be kept well ventilated to avoid fungi and they should not be exposed to high temperatures. For drying, the fruits are spread out thinly on a sheet, air-dried in a dry and well-ventilated place either in the sun or in the shade. The fruits are shaken daily and the seed removed so that it is not exposed to high temperatures longer than necessary. Within three days all fruits have normally opened. After drying, the fruits must be vigorously shaken. The fertile seeds and chaff can be separated from other inert matter by sieving, and chaff separated from the seed in a seed blower.

The seeds are orthodox and should be dried to low moisture content (4-8%). They can be stored for several years provided they are kept dry and cool. The seeds have no dormancy and need no pretreatment. On average, the weight of 1,000 seeds is 2.5-4.8 g; 456 viable seeds per gram; and 400,000-700,000 seeds/kg. Untreated seeds are sown in seedbeds, and when the seedlings have two pairs of leaves they are transplanted into containers in a free-draining loam-sand mix. After 10-12 weeks when the seedlings are about 25 cm tall they are ready for planting in the field. The species coppices readily and is easily propagated by rooted cuttings or in tissue culture. Seedlings have apigeal germination, cotyledons usually bilobed to about the centre, first 5-7 pairs of leaves are opposite and subsequent pairs sub-opposite (Jøker, 2004).

Figure 1   Flowering branch, illustration by the author, sample taken from Lad Krating Plantation, Chachoengsao

Figure 2   Three years-old Timor Mountain Gum stand at Lad Krating Plantation, Chachoengsao

Uses

Plantations are established due to the overwhelming demand for industrial wood. Timor Mountain Gum plays a very important role in afforestation in a growing number of countries, and the various wood and non-wood products that can be obtained makes it a very useful tropical tree.

The species produces a strong and durable wood, reddish in color. The bark has a tannin content of over 10% that is not yet used for commercial purpose. The wood is mainly used for pulp and boards. It is less dense than most eucalypts. The basic density is in the range of 540-570 kg/m^3. Timber from older trees can be sawn and used for general construction. Young trees provide good firewood and charcoal. The species is useful in protecting river banks and for providing shade, and because it has no major soil requirements, it is appropriate for reforestation, both in flooded soils and in dry soils in tropical lowlands. It is also a good honey-producing species (Faridah Hanum and Maesen, 1997; Joker, 2004).

Natural stands of Timor Mountain Gum in Timor consist of highly isolated fragments due to over-harvesting and deforestation. Thus, there is an urgent need to secure and maximize the supply of wood from this species. It is essential to plant them in the most suitable sites, supported with silvicultural and management practices, tree improvement, and breeding programs to meet with the demand.

Growth and yield characteristics

In simple terms, growth is the amount of glucose produced which exceeds the energy requirements of the tree, or the amount of photosynthesis minus respiration (Smith, 1997). Potential growth rate is affected by the availability of light, water, or nutrients, climatic factors (temperature, precipitation, total radiation, relative humidity, etc.), genetic structure, site characteristics, and silvicultural inputs (Cromer, 1996). As emphasized by Calaham (1962), genes play a vital role in the plant's growth mechanisms, their responses to environmental condition, and adaptation for growth. Additionally, Pipatwattanakul (1996) added that the interaction between trees can determine the share of resources that any individual tree can obtain. Tree growth and development of trees in a stand are the ultimate results of natural selection under the prevailing environment.

The term 'yield' in forestry is used in two ways. Firstly, it expresses the flow of forest products harvested from a forest at a particular time. Secondly, it is used to express the volume or amount of forest products that may be present in a stand at a given time or attainable over a period of time, without reference to whether it is actually harvested or not (Davis, 1966). The actual yield of a timber stand is the timber volume per ha harvested at the end of the rotation.

Hillis and Brown (1984) described some of the growth habits of the eucalypts. Following germination of eucalypts seedling, root growth far exceeds shoot growth

producing a prominent extension of the tap root. Seedlings native to dry areas is inclined to develop more prominent tap roots than those from moist areas. Mature seed germinates readily under favorable conditions and does not require pre-germination treatment. Seedlings usually reach 25 cm in height in 10-12 weeks. Under high relative humidity, young seedlings may be susceptible to damping-off.

The unusual bud systems of the leafy shoots in this genus offer great opportunities for remarkably rapid growth. In the axil of each leaf is a naked bud which enables continuous growth above a critical temperature, provided water and nutrients are not limiting. The stresses of extreme dry or cold season can lead to the end of growth and death of the naked bud. A second bud is dormant and concealed by petiolar and axillary tissue. Growth usually resumes when the environment is favorable, with new shoots produced from the concealed buds. Some of these buds will remain dormant until subjected to defoliation either by fire, drought, leaf-eating insects or mechanical damage. Then the dormant buds will sprout to produce epicormic shoots consisting of juvenile leaves all over the trunk and main branches (Pryor, 1976).

Some eucalypts species are able to regenerate from the progressive growth of lignotuberous seedlings and coppice, an eminent attribute in drier forests but absent in tall and wetter forest. The lignotuber is a woody swelling at the base of the seedling stem, which is an accumulation of vegetative buds, associated vascular tissue, and ample food reserves (Pryor, 1976). Species lacking the lignotuber often develop alternative survival mechanisms. These are generally prolific seed producers resulting in intense regeneration. Brooker (2002) found that stress on seedling or young plant is an important stimulus for lignotuber formation as genetic disposition.

Most eucalypt plantations are managed as coppice. The capacity of stumps to coppice may vary with species, age, season of cutting, and the environment. Normally, the ability to coppice and yield from the first coppice crop is higher than the seedling crop, but after that declines with each cropping (Evans, 1992). The eucalypt stump is best cut low (10-12cm) with a chainsaw or bow saw to provide a smooth and sloping surface. Shoots growing from the base of the stump are generally more stable than those higher up. Larger stump are generally more productive except those with thick bark and very large stumps may inhibit sprouting.

Thinning can increase the value of the remaining stems but may reduce total biomass production. For pole production it is necessary to reduce the number of shoots in the first and second year. After three or four coppicing rotation total replanting needs to take place, as annual stump mortality is often in the range 5-10% (Turnbull and Booth, 2002).

A study on the coppicing ability of *E. globulus* in Tasmania, Australia revealed that genetic diversity in coppicing traits was significant, within and between sub races after felling a 9 year-old progeny trial. Coppicing ability is influenced by three independent mechanisms, lignotuber development, enlargement of the seedling stem at the cotyledonary node, and vigorous growth. These mechanisms enhance the

eucalypts' ability to survive catastrophic damage from fires and insect, and provide useful selection traits to improve the success of coppice regeneration (Whittock *et al.,* 2003).

Crown form is genetically controlled but also greatly modified by the environment. In a young, even-aged stand all trees may have similar crown shapes. This usually changes with increasing age when competition intensifies as the crowns begin to close the canopy (Soerinegara and Lemmens, 1994). Fast-grown eucalypts are intolerant of competition and overhead cover. Therefore, the interlocking of branches and overlapping of crowns is uncommon.

Timor Mountain Gum retains its leaves during the dry season, and grows actively when moisture and temperature conditions are favorable, with a strong apical dominance. In dry locations and on shallow soils on mountain ridges, apical dominance is less pronounced and plants may develop into shrubs. With increasing size, growth is often discontinuous or regularly rhythmic (flushes) which is related to winter dormancy or pronounced dry season.

Most eucalypts selected for intensive management exhibit strong apical dominance, which result in good stem form. Species that show self-thinning in dense stands exhibit strong apical dominance. Successful self-pruning depends on the ejection of branch stubs before there has been sufficient radial growth of the stem to prevent the stub from protruding. Branch shed is less efficient in fast-grown plantations.

In its natural habitat, peak flowering of Timor Mountain Gum is strictly tied to the rainy season. Flowering usually starts within 2 years after planting and seeds are produced abundantly by 4 years of age. Fruits reach maturity about 4 months after flowering. In Brazil, flowering of two-month-old seedlings has been observed occasionally, which is related to presence of recessive gene. The early flowering character is however not within the scope of tree improvement program.

Timor Mountain Gum and its hybrids have proven as one of the fastest growing lowland species of all eucalypts for the tropical and subtropical climate. The species can obtain an annual increment of 20-30 m^3/ha with bark between 5-10 years. For example, stands of this species in Guangdong, China at a harvest age of 5 year achieve a mean height of 14 m, mean diameter of 10 cm, basal area of 20 m^2 ha $^{-1}$, volume of 120 m^3 ha $^{-1}$ and above ground biomass of 75 tonnes ha $^{-1}$. Mean Annual Increment (MAI) peaked (30 m^3 ha $^{-1}$) at age 3 to 4 years. The relative high early productivity of these eucalypt plantations is achieved in part through high initial planting densities (Baker *et al.* 2003).

Hybrids which are produced by rooted cuttings generally have higher yields. The best performing hybrids are *E. urophylla* x *E. grandis* which are planted in Aracruz, Brazil with an MAI of 35-70 m^3/ha, and *E. urophylla* x *E. alba* in Pointe Noire, Congo was 30-35 m^3/ha (Eldridge *et al.,* 1993). van Wyk *et al.* (1989) found that *E. grandis* x *E. urophylla* families outgrew other *Eucalyptus* hybrid combination

on both poor and good sites. Additionally, many hybrid clones have a relatively stable performance over different sites, which agree with expectations that hybrids might be better buffered against environmental influences than pure species clones.

As mentioned earlier there are several factors that can limit potential growth rates. Findings by Stape *et al.* (2004) indicates that water can be a limiting resource, in a clonal *E. grandis x E. urophylla* in northeastern Brazil water supply indirectly increased light and nitrogen use by increasing Leaf Area Index (LAI) and N-uptake-efficiency. In India, eucalypts with access to groundwater, near rivers and canal, exhibit higher growth rates (Dury and Manjunath, 1992). Pereira *et al.* (1989) found that fertilization and irrigation gave significant increases of biomass growth and partitioning in *E. globulus* biomass production in Portugal.

Coppice management and short rotation plantation eucalypts can remove substantial quantities of nutrients from the site causing nutritional disorders which can severely affect tree form and growth. The most common disorders result from N, P, K deficiency (macronutrients), which results in premature leaf fall and reduced wood volume. Micronutrient (B, Cu, Fe, Mn, Zn) disorders are associated with the application of fertilizers containing only macronutrients (Ca, K, N, Mg, P, S). Deficiencies of such trace elements have resulted in severe crown dieback and loss of form. Factors that affect the incidence of micronutrient disorders are soil condition, and application of fertilizers and herbicides (Dell *et al.,* 2003).

Most of the research effort on micronutrients in eucalypt plantations has been concerned with the diagnosis of disorders in the field. For example, Dell *et al.* (2001) explains the symptoms and techniques for identifying nutritional disorders in plantation eucalypts with emphasis on *E. grandis, E. pellita, E. urophylla* and *E. globulus.* Nutrition of eucalypts were also discussed by Attiwill and Adams (1996) in relation to nutritional ecology and physiology, nutrient cycling in Australian forests; nutrition and growth processes; and nutritional consequences for the management of eucalypt forests and plantations.

Dramatic growth responses can occur with corrective fertilization. For instance, at Dongmen, China mix-fertilizer (N at 100kg/ha, P at 50kg/ha, K at 50kg/ha and a trace element mix [TE]) were applied to *E. urophylla, E. cloeziana,* and the hybrid *E. grandis x E. urophylla* improved total MAI volume for trees aged between 5-11 years. The application of mixed fertilizers at planting improved volume production by 6.1 m^3/ha/yr (Simpson *et al.,* 2003).

Research has indicated that management practices and nutritional management are essential to prevent yield declines and soil degradation across rotations. Studies related to eucalypts plantation productivity with site management practices are described by Xu and Dell (2002), (2003) and Xu *et al.* (2004) for *E. urophylla* in south China, Sankaran *et al.* 2004 in India for *E. grandis* and *E. tereticornis*, Balboa *et al.* (2004) in Spain for *E. globulus,* and the CIFOR partnership project on site management and productivity (Tiarks, 2004).

Generally, their results indicated that significant soil nutrient losses have occurred leading to the degradation of site productivity potential over several rotations. Leaving harvest residues is capable of improving tree growth by increasing available nutrient supply and reducing the loss of soil organic C after tree planting. Intercropping with N-fixing trees can enhance tree growth and increase litterfall on some sites and species. Weed competition is able to deter tree growth. Controlled weeding can positively affect growth of young eucalypt stands. Furthermore, fertilizer application has a more positive response on tree growth. Nutrient conservation and replenishment measures are needed to hinder soil fertility losses.

Poor management of forest soil fertility, over-harvesting of organic matter and inadequate use of fertilizer are some of the problems in most plantations in the tropics. Hence, silvicultural treatments that reduce nutrient stress in plantation such as retention of organic matter between rotations and fertilizer additions will enhance production of stem wood by increasing leaf area, Specific Leaf Area (SLA), photosynthetic capacity, and carbon allocation to the above-ground components (Cromer, 1996). However, species that have adapted to nutrient-deficient and drought-prone sites often show limited ability to respond to fertilizer treatment (Kriedemann and Cromer, 1996 cited from Turnbull and Booth, 2002) and thus prove unsuitable for use in plantations.

Key issues concerning micronutrient requirements during mid to late rotation and for coppice in subsequent rotations are yet to be explored. The loss of micronutrients off-site with harvesting remains a concern in those areas where soil nutrient capital is limited (Dell *et al.,* 2003).

Initial stand density can also affect tree growth significantly. But, it is often related to the desired end product. For example, Kapur and Dogra (1992) suggested a spacing of 3.0 m x 3.0 m for *E. tereticornis* is best for pulpwood production. Ronggui *et al.* 2003 found that lighter thinning of young (6 to 8 years) eucalypts plantation in Yunnan, China and Tasmania, Australia did not reduce total volume increment, and growth increased significantly (up to 60%) with reduced intensities.

Another aspect of eucalypt growth patterns is seasonal variation largely shaped by the climate or weather. The irregularity of wood growth is a result of less favorable growing conditions. Growth rings are not prominent in the eucalypts and annual rings never well-designed as in temperate climate. In the eucalypts, the differentiation between sapwood and heartwood is well-marked in the darker-colored species such as *E. marginata, E. camaldulensis,* but hard to determine in lighter-colored species.

The woody trunks of eucalypts are subjected to considerable stresses during their growth, particularly those which have been fast-growing. Its importance is manifested in the wood utilization and conversion of the logs. The growth stress within the bole may cause severe end splitting in logs, distortion during sawing, and severe shrinkage during drying. Slower grown Australian trees face less difficulty in converting to planks than fast-grown overseas eucalypts (Penfold and Willis, 1961).

Provenance Trials

The transfer of forest reproduction materials, throughout the world, has reached unprecedented heights during the past few decades. Many countries have been trying to intensify their forest production by introducing new promising provenances of species (Lacaze, 1978).

The term 'provenance' is commonly used to describe the trees growing and seed collected at the original geographic origin in a natural forest. When seed is collected from planted trees the general term 'seed source' or 'landrace' (Eldridge *et al.,* 1993) is used. Landrace defined by Zobel and Talbert (1984) as a population of individuals that has become adapted to a specific environment in which it has been planted. In addition, the landrace concept is supported with other considerations such as; the original provenance must have a broad genetic base with some of the best individuals; natural and artificial selection in the past must have been intense enough to change the population genetically for better adaptation; and the plantations must be large enough to allow intense selection in the future. This should result in a population of 'best-adapted individuals' with desirable growth and form.

The concept of provenance implies that genetic patterns of variation are closely associated with the ecological conditions in which the species evolved (Turnbull and Griffin, 1986). This provenance concept is of major practical and economic significance and should be defined by the users. Provenance studies are one of the most cost-effective forms of investment in forestry research and development because as soon as superior provenances are identified, they can be put to use immediately to establish plantations simply by obtaining large quantities of seed from the selected natural forests or mature plantation.

Trials are needed whenever adequate information about certain species or planting site is lacking. Climatic and ecological matching of a new site and the original habitat of a species is rarely enough since it cannot reveal the adaptability of the species to new conditions or its ability to grow on a range of sites. For species with naturally wide geographical or ecological ranges provenance trials is essential. The sequence of provenance trials consist of three steps, namely: range-wide provenance phase, restricted provenance phase, and the provenance proving phase (Willan, 1985a).

Provenance selection program makes it possible to go further and estimate certain genetic parameters such as the heritability or genetic correlation of the main characteristics. A species and provenance selection program can supply information such as the requirements of the species, laws of variation, explanation of genetic variation resulting from the selection pressure exerted by variations in environmental factors, genotype-environment interactions, evolution of the species, and the effects of selection pressure. The transfer of species to new environments coupled with the effect of selection pressure leads to the creation of new population or land races (Lacaze, 1978).

Timor Mountain Gum was tested in species and provenance trials and is now widely planted in plantations in the tropics. Examples of provenance trials of this particular species are described by de Figueredo Luz *et al.* (1996) in Brazil, Wei (1996) in China, Dudley and Osgood (1996) in Hawaii, Lakusta (1981), Pinyopusarerk (1989) and Luangviriyasaeng (2003) in Thailand, Le *et al.* (2003) in Vietnam, and Siagian (2004) in Indonesia. Seed collected from selected trees in the provenance trials can be used to establish seed production area (SPA) and for further testing in progeny tests.

The main outcome from the provenance trials has been the demonstration that provenances from altitudes of above 1500m perform poorly in the lowland tropics. Moreover, those provenances from lower altitudes (300-1100m) and from drier locations grow well in humid and sub-humid tropical and subtropical conditions with a dry season of 1-5 months in the coolest part of the year (Faridah Hanum and Maesen, 1997). In general, progenies from low altitudes in Flores, Alor, and Timor grew fastest. In Thailand, initial objectives of eucalypts provenance trials were to determine the best provenances for fuelwood and charcoal production, and those objectives have shifted according to the priority of current end use, for pulpwood.

Progeny Testing

The progeny of a tree refer to their offspring. Therefore, a progeny test is a method used for assessing the genotype of an individual or of the performance of a parent by a study of its progenies under controlled conditions (Rieger *et al.*, 1976). Parent trees are either partially or fully known identity. The purpose of progeny tests are to serve all or most of the following five objectives (Eldridge *et al.,* 1993): estimation of the breeding value of selected parents; a source of selected trees for the next generation; estimation of genetic parameters; demonstration purposes; and seedling seed orchard. Progeny tests are indispensable in a program based on phenotypic selection and where environmental influences are unknown.

The most common experimental design used in progeny testing is the Randomized Complete Block Design (RCBD) to promote open-pollinated progenies. The major advantages of the open-pollinated progenies are that they are inexpensive, simple to perform, yield information rapidly, and can satisfy all the objectives of progeny testing. Seed lots are planted in RCBD, which will yield the information and material needed for a practical breeding program within five years for tropical eucalypts, and within ten years for temperate species. Converting a progeny test to a seedling seed orchard (SSO) is a very attractive option for species that flower profusely at an early age (Eldridge *et al.,* 1993). However, they are typically freely pollinating, and the exact degree of inbreeding is unknown (Quijada, 1985).

For example, Tridasa and Sipayung (1996) described the conversion of open-pollinated progeny test of *E. deglupta* in Kalimantan, Indonesia to SSO to enable genetic gains from family and within family selection. Converting progeny tests to

SSO will provide the opportunity to produce genetically improved seeds for operational planting program.

Open pollinated-progeny test of Timor Mountain Gum were established on multiple sites to identify new families or clones that can grow quickly in a consistent manner over large areas of southern China. The testing indicated that Timor Mountain Gum may also adapt to the subtropical climatic region, and that progenies from the provenances of Mt. Egon, Flores Islands, Indonesia grow well at all the sites. In China, the management phases of Timor Mountain Gum have involved seed orchards, second generation seed orchards, and clonal seed orchards through early selection of mother trees (Xu *et al.*, 2003).

Testing is also carried out to test the progenies of hybrid eucalypts. Bierwagen *et al.* (1996) found that stand density had significant influence on DBH, height, volume, and family means in a progeny and stand density trial of *E. grandis* which was established in Brazil in 1991. Larger heritability and smaller phenotypic variance were found in higher stand density of 3 years-old progenies.

In Brazil, open pollinated progeny test are carried out for natural hybrid trees of *E. pellita x E. resinifera* and provenance-progeny trials of *E. pellita* (25 wild half-sib progeny) (de Figueredo Luz *et al.*, 1996). The hybrids grew better than their parental species and were more adapted to sandy soils. Growth variation was significant between *E. pellita* provenances, and between progenies of the hybrid population. The tests are aimed at selecting plus trees and verifying the implication of natural hybrids in improvement program. These materials are suitable for timber production on poor soils.

Hybridization is extensively used for its capacity of combining desirable traits of several species. This allows for the production of low cost and high quality raw material for industrial purposes. The hybrid *E. urophylla* x *E. grandis* were used in Brazil (de Assis, 2000), Congo (Souvannavong, 1992 and Bouvet and Vigneron, 1996), and China. Eucalypts hybrids are fertile and frequently continue to show some functional heterosis in advanced hybrid combination, which can be used to transfer or to receive outstanding characteristics. However, SSO that were established in 1970 in Congo had resulted in uneven seed production and heterogeneous hybrid progenies. In later years, with the implementation of recurrent selection scheme in Congo, genetic gain can be expected in growth, morphological and wood property traits. Male additive variance (*E. grandis*) was lower than female (*E. urophylla*), due to the phenotypic selection of the male. Additive variance represented more than 70% of the genetic variance for the different traits.

Classical tree breeding methodology has been aimed at capturing additive genetic variance by selecting on phenotypic performance (mass selection) or using open- or controlled-pollinated progeny test information as a basis for recurrent selection and advancement of a single breeding population (Bridgwater and Franklin, 1985 cited from Griffin, 1989). Therefore, the progeny test is the next essential step after the provenance trials in the tree breeding program.

Tree breeding programs for *Eucalyptus* is now in progress in Thailand (Luangviriyasaeng, 2003), Vietnam (Le *et al.,* 2003), China (Wei, 1996), Brazil, South Africa, Congo and supported financially and technically by Australian-based organizations Australian Centre for International Agricultural Research (ACIAR), Australian Agency for International Development (AusAID) and CSIRO Forestry and Forest Products, CSIRO Tree Seed Centre, which promotes the domestication and improvement of mostly Australian native species outside this continent. These efforts are accompanied with training, technological transfer, and local capacity-building.

Breeding of eucalypts for traits of commercial importance is a relatively recent development and linked to the increase in the establishment of plantations. Earlier studies on genetics of eucalypts concentrated on tree growth, survival, stem straightness and branch quality. The progress of breeding programs has included fitness, which relate to the ability of trees to survive environmental threats, more importantly wood quality, coppicing ability, and rooting capacity of cuttings is an additional prerequisite for mass vegetative production. Some of the environmental threats used as criteria for breeding program are frost, drought, wind, insects and diseases, and unfavorable soil conditions (salinity, alkalinity, acidity or water-logging).

The importance of a breeding program is to produce improved seed sources or other improved planting materials. Li *et al.* (2003) found that improved *E. grandis* seed sources from Florida and Aracruz generally outperformed unimproved sources. It reflects upon the advanced stage of tree improvement achieved by Florida and Aracruz programs.

MATERIALS AND METHOD

The study area

The study on Timor Mountain Gum provenances and its progenies were carried out at Lad Krating Plantation of Sanam Chaikhet District in Chachoengsao province (Figure 3 and Figure 4). The plantation is situated about 90 km east of Bangkok, at latitude 13° 42'N and longitude 101° 06'E. The Timor Mountain Gum provenance trials and progeny testing are located at P5/4 and P6/2 respectively in the plantation area (Figure 5). The area is relatively flat, at an altitude of 80m amsl. Mean annual temperature and annual rainfall is 28°C and 1,220mm respectively. The dry period ranges between November to February, and the maximum peak rainfall is in September, illustrated in the climatic diagram of Lad Krating Plantation (Figure 6).
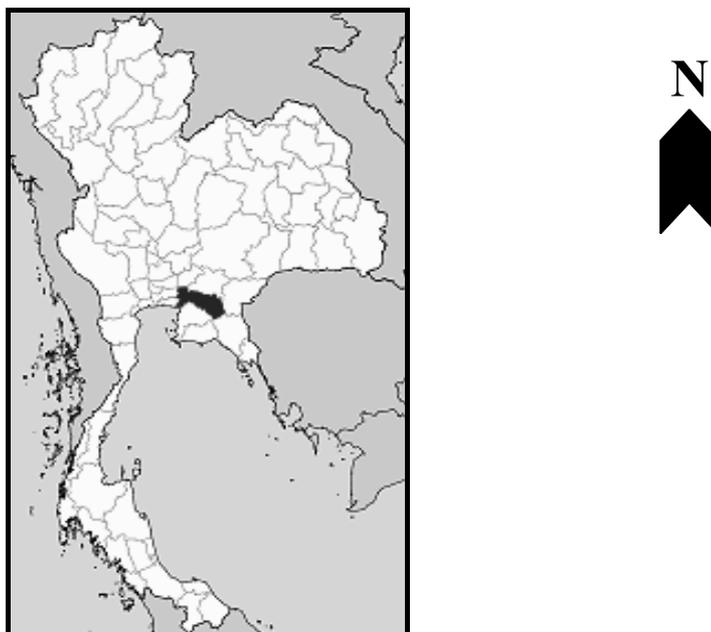

Figure 3   The location of Chachoengsao province, Thailand

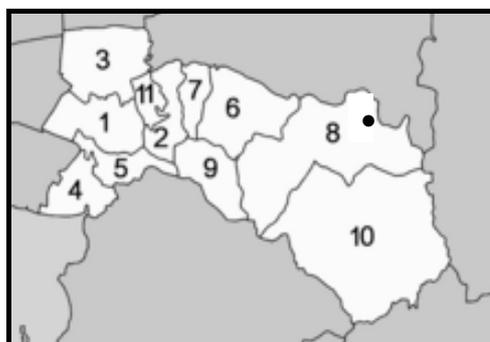Figure 4   The location of TPC Lad Krating Plantation, in Sanam Chaikhet District (8) Chachoengsao province
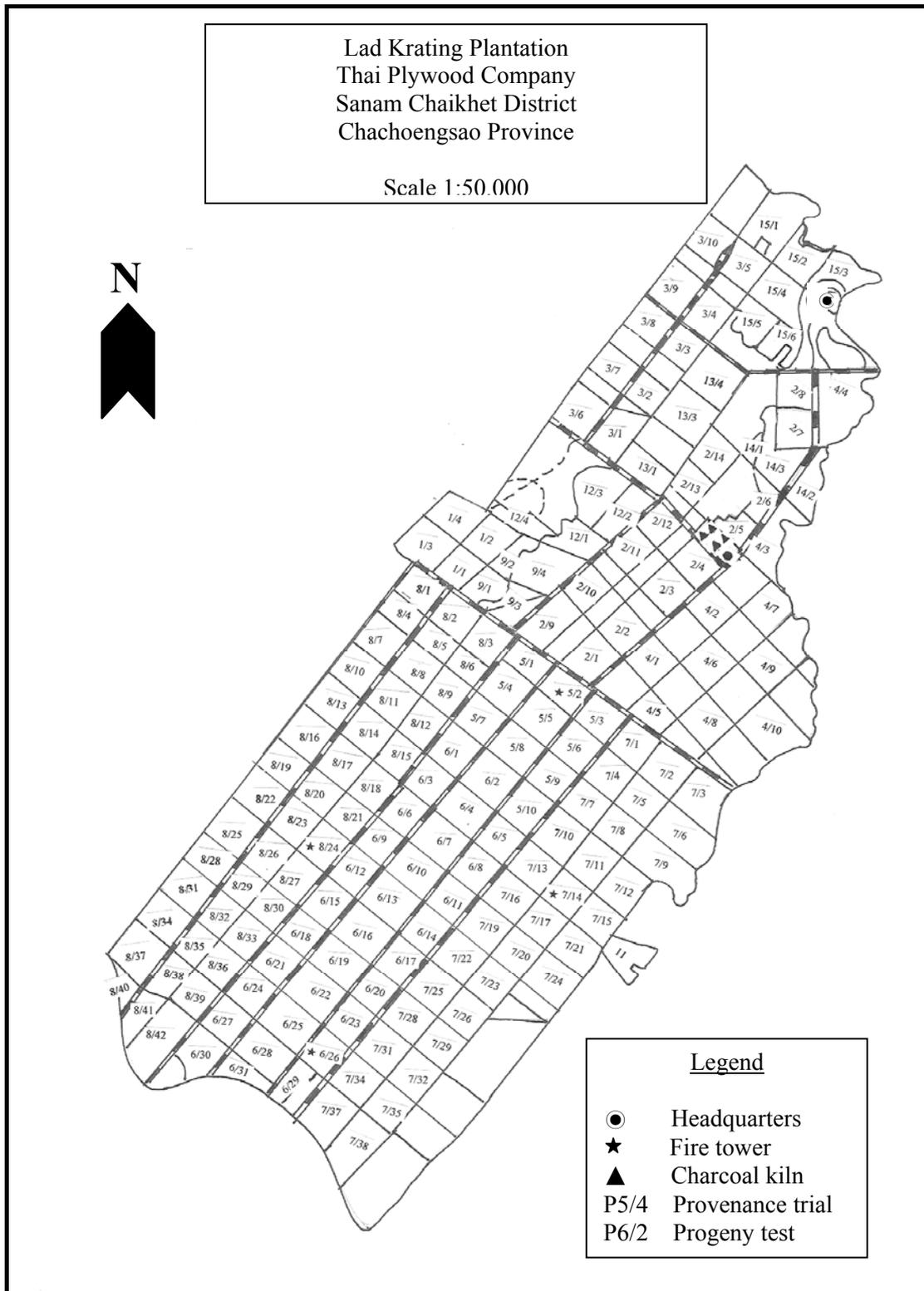
Figure 5   Location of provenance trials and progeny tests of Timor Mountain Gum
            in TPC Lad Krating Plantation, Chachoengsao
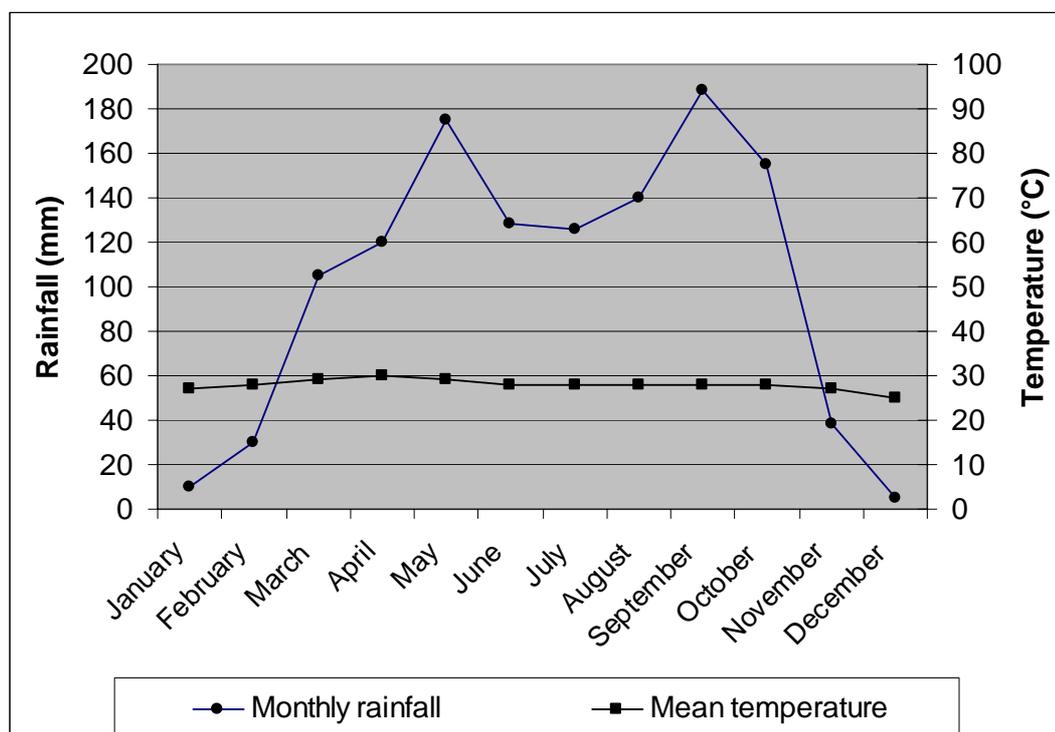
Figure 6   Climatic diagram of Lad Krating Plantation, Chachoengsao, Thailand. Data was adapted from meteorological records for the period 1999-2004.

According to the Pedon Classification, Lad Krating's sandy clay loam soil belongs to the Clayey-skeleton, Kalinite, Aeric Kanhapustult Series (Winrock International, 1988). This soil contains approximately 49% sand, 27% silt, and 24% clay.

Provenance trials

1. Seed sources

The Timor Mountain Gum provenance trials were established in 1988, using 23 seed sources from Indonesia and East Timor. These included 7 sources from Flores Island, 7 sources from Timor Island, 2 sources from Alor Island, 1 source from Lomblen Island, 3 sources from Wetar Island, and 3 sources from Pantar Island (Table 1). Referring to Table 1, provenances marked with the asterisk (*), indicate that these are not included in most of the analyses due to total mortality of the provenance, inadequate replication, or are absent from testing. The location of these islands collectively known as the Lesser Sunda Islands or Nusa Tenggara, in Southeast Asia is illustrated in Figure 7. A diagram of the natural distribution of seed sources is presented in Figure 8.

Table 1   Natural seed sources of Timor Mountain Gum used in establishing the Timor
Mountain Gum provenance trials

Provenance Code	Location of Seed Collection	Altitude M ASL	Latitude (S)		Longitude (E)	
			Deg	Lib	Deg	Lib
1	Mt. Egon (Flores)	400 - 890	8	36	122	28
2	Mt. Wulogai (Flores)	1140 – 1240	8	33	121	48
3	Mt. Wokoh (Flores)	850 - 900	8	33	122	36
4	Mt. Lewerok (Flores)	500 - 550	8	15	122	40
5	Mt. Mandiri (Flores)	500 - 650	8	30	122	54
6	Mt. Lewotobi (Flores)	450 - 550	8	22	123	39
7	Mt. Kerbau (Lomblen)	420 - 820	8	22	123	36
8	Mt. Boleng (Flores)	915 – 1025	8	21	123	35
9	Kalabahi (Alor)	450 - 850	8	10	124	41
10	Ampui (Alor)	800 - 1200	8	10	124	41
11	Mt. Sirung (Pantar)	760	8	26	124	03
*12	Mt. Mutis (Timor)	800 - 2200	8	34	124	11
13	Mt. Delaki (Pantar)	680 - 780	8	26	124	03
14	Mt. Wasbilla (Pantar)	750 - 800	8	34	124	14
15	Remexio (Timor)	800 - 930	8	35	125	41
*16	Hatuloi (Wetar)	250	7	54	125	58
*17	Ulubaha (Wetar)	150	7	54	125	58
18	Lelogama (Timor)	1200 - 1300	9	34	124	20
19	Ermera (Timor)	500 - 1400	9	13	125	40
*20	Dare (Timor)	530 – 575	8	35	125	41
*21	Balebar (Timor)	700 – 725	8	35	125	31
22	Ililaku (Wetar)	350 – 550	7	54	125	58
23	Mt. Lakaan (Timor)	1350 – 1550	9	34	124	05
*24	Aileu (Timor)	1100 – 1300	9	13	125	40
*25	Ilwaki (Wetar)	450 -550	7	34	126	21

Figure 7   The Location of the Lesser Sunda Islands in Southeast Asia
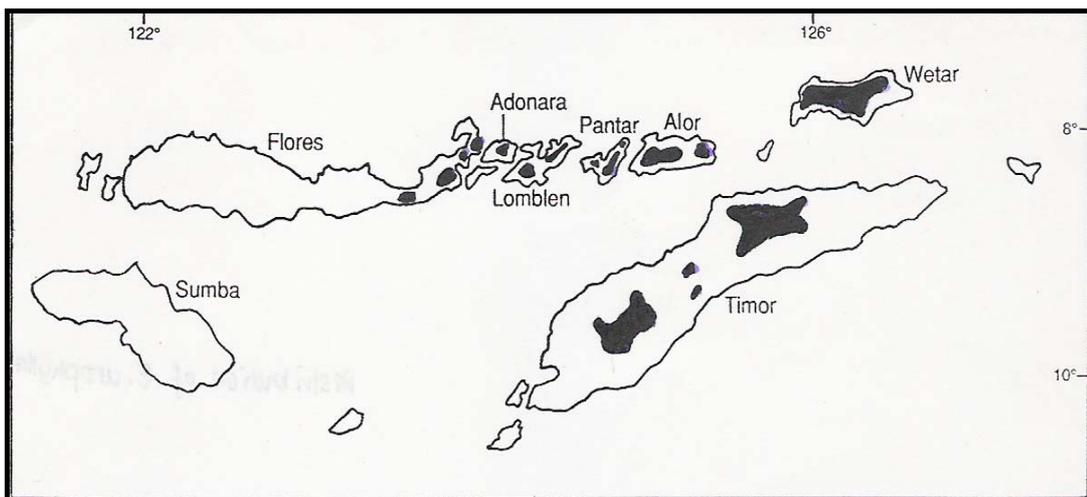
Figure 8   The natural distribution of seed sources of Timor Mountain Gum on
            the group of Lesser Sunda Islands

2. Experimental design and management of trials

The provenance trials of Timor Mountain Gum were established by using a
Randomized Complete Block Design (RCBD) with 4 replications (Figure 9). The
total land area used for the provenance trials is 20 rai (3.2 ha). The trials consist of 20
plots and each plot contains five rows of five trees planted at 4m x 4m spacing. Each
plot is 20m x 20m. There are 25 trees in each plot. The experiment also includes 9
rows of *Casuarina junghuniana* as shelterbelts. Weeding was carried out every 2
months in the first year, every 3 months in the second year, twice a year in the third
year, and once a year after the fourth year. Additionally, weeding was also done to
aid data collection.

BLOCK 2

5	12	7	2
10	6	19	23
11	14	3	15
9	28	1	8
16	4	13	22

BLOCK 3

6	14	22	13
12	16	5	19
11	2	18	23
9	4	3	8
10	1	7	15

ROAD   6m

23	5	6	3
4	7	2	14
18	1	11	9
10	19	20	15
12	22	8	13

19	11	13	23
15	6	4	18
1	7	14	5
3	12	9	8
10	20	2	22

BLOCK 1   BLOCK 4
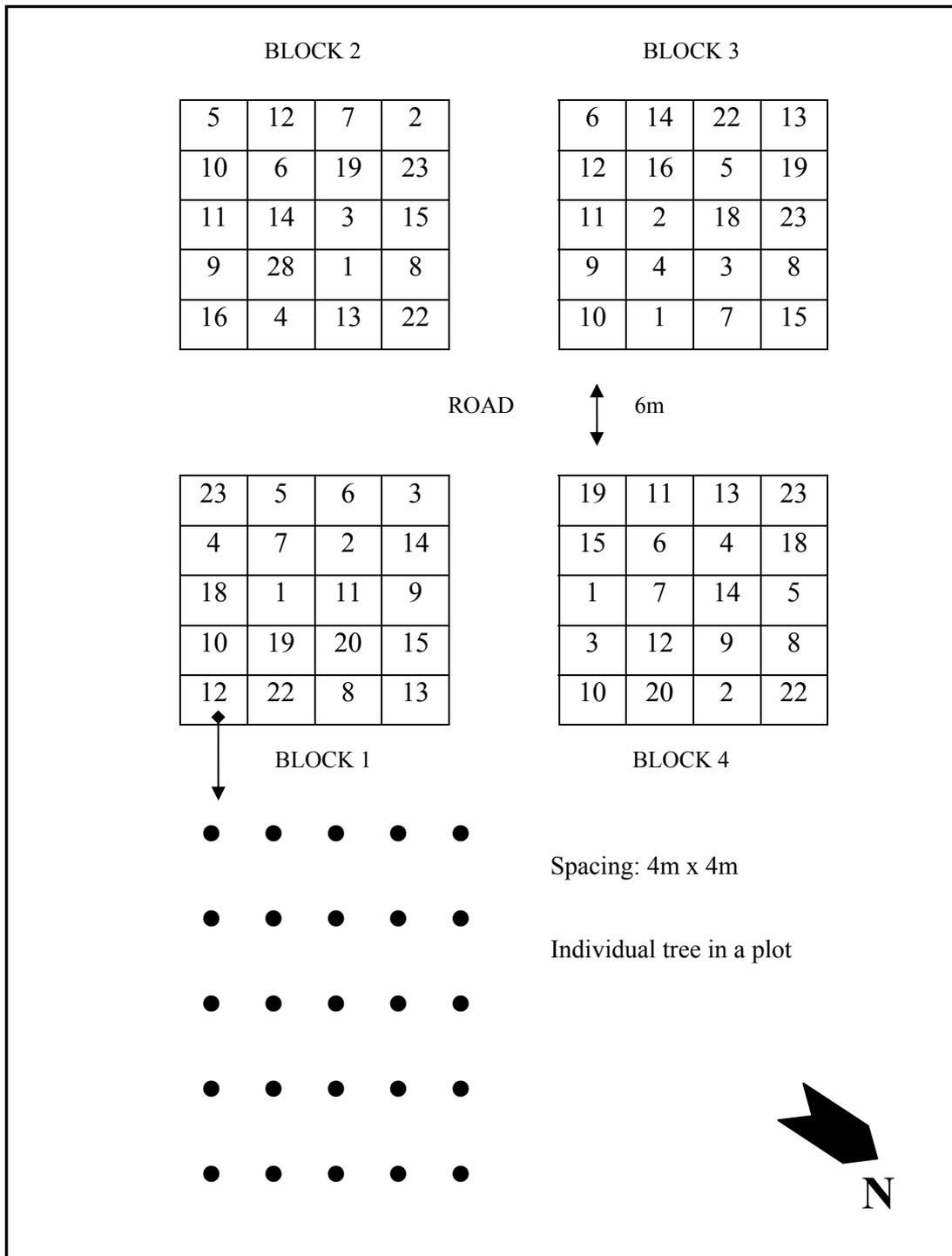
Spacing: 4m x 4m

Individual tree in a plot

N

Figure 9   Experimental design of Timor Mountain Gum provenance trials established in 1988 at Lad Krating Plantation, Chachoengsao

3.   Measurement of tree performances

Tree characteristics such as the height, diameter 10cm above-ground level (D10), and diameter at breast height (DBH) of trees were measured using the Suunto hypsometer and calliper respectively. Crown diameter was measured using meter tape. All trees were also assessed visually for stem forms and bark types. In addition, 8 samples were taken from each bark type category for bark thickness assessment.

Variation of leaf dimensions (leaf area, length, and maximum width) was conducted. Twenty five mature leaves were randomly selected from at least 2 randomly selected trees of each selected provenance. The leaves were randomly collected from the southern part of the crown portion. Leaf dimensions were measured using LI-COR Portable Area Meter Model 3000A at the Department of Silviculture, KUFF (Faculty of Forestry, Kasetsart University).

Stomatal frequency (stomata/mm^2) was calculated from 8 leaf samples per provenance which were randomly collected from the southern part of the crown portion. In Timor Mountain Gum, stomata are distributed on the abaxial (underside) leaf surface.

Variation of tree performances and traits were analysed using the Analysis of Variance (ANOVA). The Duncan's New Multiple Range Test (DNMRT) was used to evaluate various characteristics among the provenances.

Progeny test

1.   Seed sources

The seeds from the selected 188 mother trees (plus trees) of Timor Mountain Gum were tested for initial growth rates and survival. The best performing 80 families were selected to establish the progeny tests (Table 2).

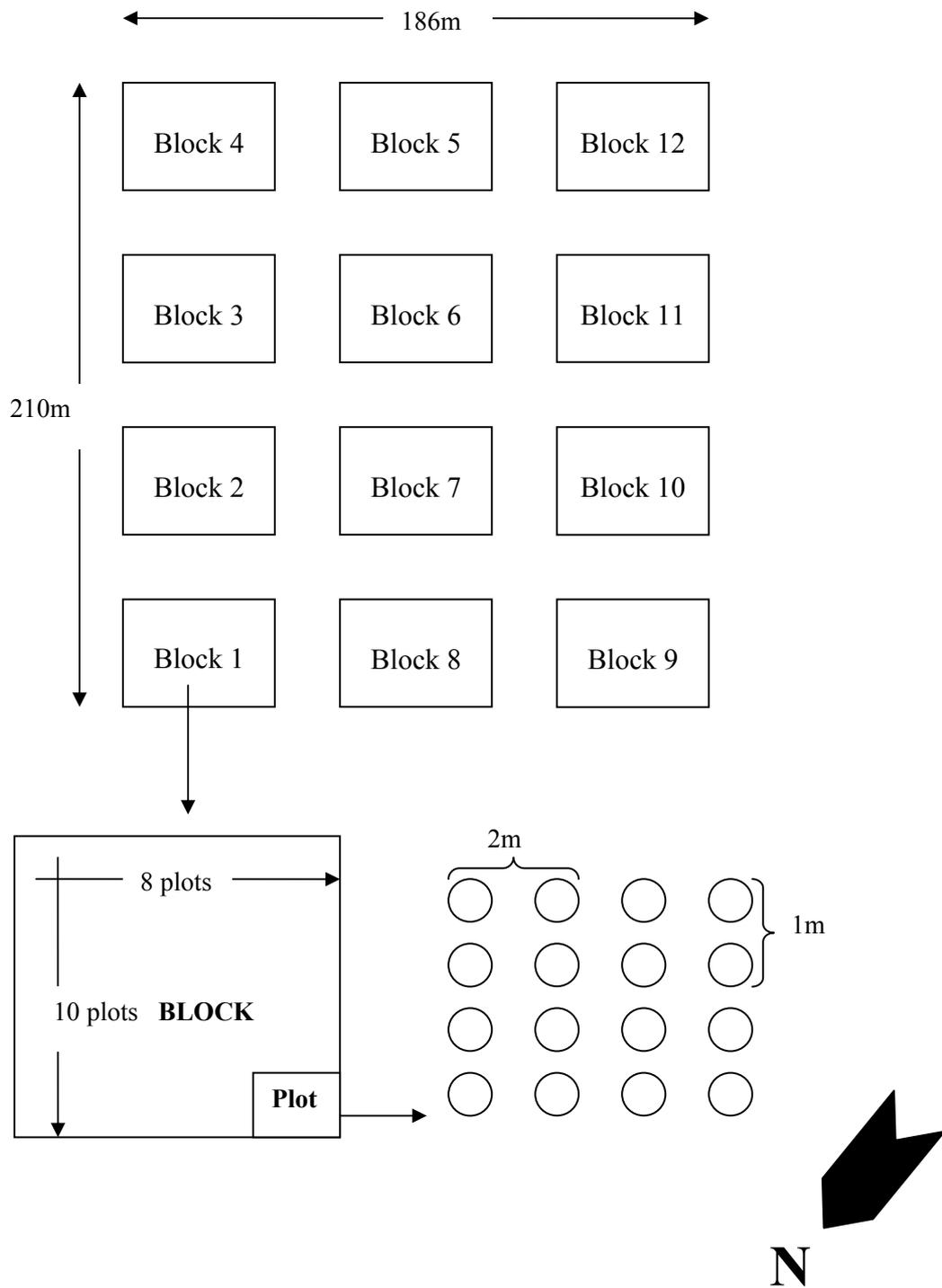2.   Experimental design and management of tests

The progeny tests of Timor Mountain Gum were established using a Randomised Complete Block Design (RCBD) with 12 replications or blocks in May 2002 (Figure 10). Road system was 6m wide within the testing area. Each block consists of 80 plots, which were planted with 4 rows of 4 trees with a spacing of 2m between columns and 1m between rows (Figure 11).

Table 2 Plus tree of Timor Mountain Gum provenances tested in the progeny tests,
Lad Krating Plantation, Chachoengsao

Progeny No	Plus Tree Registration No	Provenances	Progeny No	Plus Tree Registration No	Provenances
1	TK0114 Eu 0002	Mt. Lewerok, Flores	41	TK0114 Eu 0094	Mt. Lewotobi, Flores
2	TK0114 Eu 0004	Ampui, Alor	42	TK0114 Eu 0095	Mt. Mutis, Timor
3	TK0114 Eu 0005	Ampui, Alor	43	TK0114 Eu 0097	Mt. Lewotobi, Flores
4	TK0114 Eu 0006	Ampui, Alor	44	TK0114 Eu 0098	Mt. Lewotobi, Flores
5	TK0114 Eu 0011	Ampui, Alor	45	TK0114 Eu 0100	Mt. Lewotobi, Flores
6	TK0114 Eu 0014	Mt. Lewerok, Flores	46	TK0114 Eu 0104	Mt. Sirung, Pantar
7	TK0114 Eu 0019	Ermera, Timor	47	TK0114 Eu 0106	Mt. Sirung, Pantar
8	TK0114 Eu 0020	Ermera, Timor	48	TK0114 Eu 0107	Mt. Lewotobi, Flores
9	TK0114 Eu 0021	Mt. Egon, Flores	49	TK0114 Eu 0110	Mt. Wulogai, Flores
10	TK0114 Eu 0023	Mt. Egon, Flores	50	TK0114 Eu 0111	Hatuloi, Wetar
11	TK0114 Eu 0024	Mt. Sirung, Pantar	51	TK0114 Eu 0112	Mt. Wasbilla, Pantar
12	TK0114 Eu 0026	Mt. Sirung, Pantar	52	TK0114 Eu 0113	Mt. Wasbilla, Pantar
13	TK0114 Eu 0028	Mt. Wasbilla, Pantar	53	TK0114 Eu 0117	Mt. Wokoh, Flores
14	TK0114 Eu 0030	Mt. Wasbilla, Pantar	54	TK0114 Eu 0118	Mt. Wokoh, Flores
15	TK0114 Eu 0037	Mt. Mandiri, Flores	55	TK0114 Eu 0119	Mt. Wokoh, Flores
16	TK0114 Eu 0041	Kalabahi, Alor	56	TK0114 Eu 0120	Mt. Wasbilla, Pantar
17	TK0114 Eu 0042	Mt. Sirung, Pantar	57	TK0114 Eu 0121	Mt. Wasbilla, Pantar
18	TK0114 Eu 0049	Mt. Lewotobi, Flores	58	TK0114 Eu 0127	Mt. Kerbau, Lomblen
19	TK0114 Eu 0050	Mt. Lewotobi, Flores	59	TK0114 Eu 0128	Lelogama, Timor
20	TK0114 Eu 0051	Mt. Wasbilla, Pantar	60	TK0114 Eu 0129	Mt. Mandiri, Flores
21	TK0114 Eu 0053	Mt. Lewerok, Flores	61	TK0114 Eu 0132	Lelogama, Timor
22	TK0114 Eu 0054	Mt. Wasbilla, Pantar	62	TK0114 Eu 0133	Lelogama, Timor
23	TK0114 Eu 0055	Mt. Wasbilla, Pantar	63	TK0114 Eu 0135	Mt. Kerbau, Lomblen
24	TK0114 Eu 0056	Mt. Lewotobi, Flores	64	TK0114 Eu 0138	Lelogama, Timor
25	TK0114 Eu 0058	Mt. Mutis, Timor	65	TK0114 Eu 0139	Lelogama, Timor
26	TK0114 Eu 0062	Mt. Egon, Flores	66	TK0114 Eu 0140	Lelogama, Timor
27	TK0114 Eu 0064	Mt. Wokoh, Flores	67	TK0114 Eu 0144	Lelogama, Timor
28	TK0114 Eu 0066	Mt. Kerbau, Lomblen	68	TK0114 Eu 0147	Remexio, Timor
29	TK0114 Eu 0067	Mt. Egon, Flores	69	TK0114 Eu 0149	Mt. Lakaan, Timor
30	TK0114 Eu 0068	Mt. Egon, Flores	70	TK0114 Eu 0150	Mt. Lakaan, Timor
31	TK0114 Eu 0072	Ermera, Timor	71	TK0114 Eu 0151	Ermera, Timor
32	TK0114 Eu 0074	Ermera, Timor	72	TK0114 Eu 0153	Ermera, Timor
33	TK0114 Eu 0075	Mt. Wokoh, Flores	73	TK0114 Eu 0157	Mt. Boleng, Flores
34	TK0114 Eu 0077	Mt. Delaki, Pantar	74	TK0114 Eu 0163	Mt. Egon, Flores
35	TK0114 Eu 0078	Mt. Delaki, Pantar	75	TK0114 Eu 0167	Mt. Egon, Flores
36	TK0114 Eu 0081	Mt. Wulogai, Flores	76	TK0114 Eu 0169	Mt. Egon, Flores
37	TK0114 Eu 0083	Mt. Wulogai, Flores	77	TK0114 Eu 0170	Mt. Egon, Flores
38	TK0114 Eu 0085	Remexio, Timor	78	TK0114 Eu 0175	Kalabahi, Alor
39	TK0114 Eu 0086	Remexio, Timor	79	TK0114 Eu 0191	-
40	TK0114 Eu 0093	Mt. Sirung, Pantar	80	TK0114 Eu 0184	Ililaku, Wetar

9	73	50	62	49	71	23	12	75	12	56	55	14	37	77	21	42	43	65	56	63	22	55	75
28	39	31	75	16	33	64	3	34	51	33	2	78	4	6	19	9	34	50	76	14	26	80	13
38	6	7	13	25	46	34	53	22	43	28	61	13	26	76	72	70	44	5	7	57	32	79	12
24	19	48	56	68	47	4	65	52	39	47	3	45	62	16	8	40	58	39	17	67	15	78	61
2	66	76	30	14	35	18	40	36	69	42	38	67	49	41	25	59	53	77	31	72	35	23	74
21	44	27	69	15	54	52	32	71	10	70	1	46	74	73	30	33	16	19	69	60	29	27	48
11	72	63	42	36	37	8	70	9	35	53	63	79	7	68	64	30	41	11	36	25	24	51	4
43	59	57	67	78	58	20	29	31	58	59	54	23	65	48	20	62	1	10	68	66	47	54	18
17	55	74	61	80	45	77	79	60	44	11	40	80	32	17	57	8	52	37	71	20	45	64	49
51	26	5	60	10	22	41	1	15	5	29	66	24	27	18	50	38	21	2	6	3	73	46	28
22	37	31	41	16	8	4	49	41	46	8	67	59	38	35	5	67	43	42	69	15	11	58	1
36	21	42	1	35	34	27	15	45	11	74	50	24	4	48	39	57	63	40	2	76	46	39	36
55	76	58	29	52	2	53	20	51	40	7	61	80	72	44	62	12	27	74	25	52	45	26	22
10	62	25	44	39	65	6	7	2	20	66	53	75	78	58	27	55	47	32	51	23	64	50	16
9	79	17	26	71	40	74	46	65	33	37	49	69	30	1	56	3	65	73	71	59	79	44	75
66	75	13	14	77	51	43	47	73	17	25	29	77	32	13	76	56	29	18	14	53	7	10	66
50	28	67	18	70	45	48	5	57	12	71	14	19	52	6	70	38	72	24	41	19	13	62	68
64	61	19	11	30	32	69	78	55	26	18	63	43	15	60	47	70	20	21	17	54	31	30	34
38	54	24	68	59	73	3	57	22	3	42	10	36	79	31	23	37	5	61	80	4	49	33	8
12	56	72	60	80	63	33	23	9	68	21	34	16	64	28	54	77	9	28	78	60	35	6	48
75	37	80	46	40	48	53	28	11	1	34	47	60	23	32	67	33	29	73	18	70	12	39	36
32	2	55	38	45	30	29	54	65	33	68	13	4	42	70	3	15	58	57	42	24	65	45	72
13	39	36	65	5	16	25	12	56	64	19	51	27	71	72	49	37	32	11	35	61	7	5	60
59	51	71	79	49	77	19	31	7	80	18	22	15	8	12	48	17	40	2	44	28	66	69	79
62	56	22	64	76	14	8	74	28	6	26	78	75	43	44	58	80	26	74	30	13	4	22	63
67	70	66	50	24	15	7	27	74	61	37	16	46	10	69	52	59	34	68	51	56	14	54	78
21	73	20	6	68	10	44	69	14	24	17	63	54	35	30	9	55	16	20	43	50	9	47	19
42	57	3	33	34	60	43	72	36	41	38	66	2	40	29	21	75	23	49	31	10	52	67	71
61	78	52	11	9	63	17	18	31	45	5	73	62	55	53	50	6	41	1	38	3	46	62	8
26	41	58	1	4	35	23	47	79	76	39	20	25	59	57	77	77	64	76	25	53	27	21	48
56	5	27	37	19	21	38	59	31	2	11	27	64	43	26	69	44	61	69	12	45	14	18	4
25	76	55	39	32	64	2	15	74	53	16	49	55	23	57	73	13	78	39	17	34	55	7	52
17	35	43	80	69	65	50	40	39	20	41	30	21	9	38	19	19	11	76	68	73	62	60	57
24	29	11	1	30	60	45	44	3	18	51	34	1	75	65	7	80	9	67	2	65	58	64	71
71	20	14	54	78	26	70	57	24	66	4	13	63	50	47	62	53	77	21	48	24	51	37	56
22	61	79	58	9	77	34	74	22	59	33	5	56	58	8	67	35	3	6	31	41	59	75	10
41	28	6	63	3	18	46	36	36	48	10	35	77	54	15	37	1	50	42	29	70	36	26	49
33	16	66	31	23	49	4	10	71	70	44	28	25	80	72	32	74	43	46	38	20	5	47	22
7	62	51	42	67	52	12	72	40	12	68	45	76	29	46	17	28	66	32	40	15	79	23	16
47	68	73	8	53	75	13	48	78	52	6	14	79	60	42	61	54	8	72	27	33	25	30	63

Figure 10 Progeny test of Timor Mountain Gum established in June 2002 at Lad Krating Plantation, Chachoengsao

186m

210m

Block 4

Block 5

Block 12

Block 3

Block 6

Block 11

Block 2

Block 7

Block 10

Block 1

Block 8

Block 9

8 plots

10 plots **BLOCK**

Plot

2m

1m

N

Figure 11 Experimental design of Timor Mountain Gum progeny tests at Lad Krating
Plantation, Chachoengsao

Weeding regime is similar with the provenance trials. *Acacia mangium* were used for shelterbelts. The stand was thinned successively at 2½ years old (October 2004) and at about 3 years old (June 2005). Initially, there were 16 trees per plot. At each thinning, 50% of trees were cut. After the final thinning and selection, only 1 tree per plot will remain. After the second thinning in June 2005, some potential mother trees were selected for seed production. Final thinning will convert the progeny tests to a seedling seed orchard.

3. Measurement of tree performances

After the second thinning, tree height, DBH, D10, crown diameter were measured and stem form assessed in October 2005. Variation of tree performances were analysed using the ANOVA.

4. Above-ground biomass study

Representative sample trees were predetermined after the marking and selection of trees to be thinned out (second thinning). The trees were classified into five diameter classes. Five sample trees for each diameter class were selected for destructive sampling. After felling, different parts of the tree, the stem, branches, leaves, and flowers or fruits were weighted separately in green weight. Then, a small representative portion of the different parts of the tree were separated, weighted green (within 24 hours), sealed and brought to the laboratory for drying. The representative samples were oven-dried for 48 hours (or constant weight) at 80°C, cooled in desiccator jars, and re-weighted. Plant biomass determination was described by the EPA, USA (1994). The study was conducted at the laboratory of Department of Silviculture, KUFF. The total dry weight of each component of the tree is then estimated by applying the ratio of fresh weight to dry weight with the following formula (Jayaraman, 2000):

$$\sum \text{DW of tree} = \frac{\text{DW of samples from bole}}{\text{FW of samples form bole}} \left(\sum \text{FW of bole} \right)$$

(1)

Where:
DW = Dry weight
FW = Fresh weight

Biomass, DBH or D10 and height of sampled trees were utilized to develop prediction equations through regression techniques. Volume or biomass is the dependent variable and functions of DBH and height form the independent variables in the regression. The allometric equation used to predict biomass is given here (Jayaraman, 2000).

$$Y = a + b\, D^2\, H \qquad\qquad (2)$$

Where:

Y	= Tree biomass
D	= Diameter
H	= Height
a, b	= Regression coefficients

Harvest index

The harvest index (HI) was also estimated using the following equation:

$$HI = (\text{Stem biomass/Total above-ground biomass}) \times 100 \qquad (3)$$

Crown ratio (K/d ratio)

The crown ratio was estimated. The crown diameter and the DBH are closely correlated and may be predicted from the other rather accurately. The *K/d* ratio reflects the feasibility of higher stocking in terms of basal area per hectare and the probability of higher volume per hectare growth rates. Investigation of *K/d* ratios provides a useful means of checking the validity of yield tables and other growth models. *K* (crown diameter) is usually measured in metres and *d* (DBH) in centimetres (Phillip, 1994).

$$\text{Crown ratio} = K/d \qquad\qquad (4)$$

Form quotients

The form quotients were assessed. Taper is the rate of change of diameter over a specified length or height. Form quotients are ratios of two diameters, one of which is usually DBH, while other form quotients use a diameter at a specified proportion of total height from the ground (Philip, 1994).

$$\text{Form Quotients} = \frac{\text{Diameter at 6m above-ground level}}{\text{DBH}} \qquad (5)$$

5. Heritability estimates

Heritability is the statistical expression for the relative contributions of genotype and environment to the phenotype, and is useful in predicting gain from selection. The current families are half-sib progenies. Therefore, narrow sense family heritability (h^2_f) was estimated with the formula below (Zobel and Talbert, 1984).

$$h^2_f = \frac{\sigma^2_f}{\sigma^2_f + (\sigma^2_e/n)} \qquad (6)$$
$$= 1 - 1/F \qquad (7)$$

Where:

σ^2_f	= Variance among families
σ^2_e	= Error variance
n	= Number of individuals per family
F	= F-ratio of families from ANOVA

The narrow sense heritability is the ratio of additive gene variance (σ^2_f) to the total phenotypic variance. In this study, heritability was estimated from the half-sib progeny test, ANOVA and compute heritability as a function of the variances. As mentioned by Heddrick (2000), when heritability is closer to 0.0 the greater the effect of environment on phenotypic variance, and when it is closer to 1.0 genetic factor has a greater impact. The phenotype and genotype values were calculated with the following formula by Falconer (1960).

$$G = h^2 \text{ x } P \qquad (8)$$

Where:

G	= Genotypic value (%)
h^2	= Heritability
P	= Phenotypic value (%)

$$P = \frac{\text{Mean value of families} - \text{Total mean average}}{\text{Total mean average}} \text{ x } 100 \qquad (9)$$

RESULTS AND DISCUSSION

Provenance trials

The present result of growth characteristics from the provenance trials of Timor Mountain Gum were compared with those obtained by Maelim (2000).

1. Survival percentages

One of the most important results of species and provenance trials is the survival percentages. It can also reflect upon distinct variations of other tree growth characteristics when grown under a single condition, whether of local or exotic species. But, it is important to note that Timor Mountain Gum is an introduced tree species that has to adapt to the new environment and fluctuating climate conditions. The survival of tropical trees under plantation conditions also depends on the tree adaptation, biotic and abiotic damage, soil type and other environmental factors. Timor Mountain Gum has the most limited distribution of all eucalypts species, where it was found naturally only on the Lesser Sunda Islands. But, it still is one of the most variable of all eucalypts. It does have the largest altitudinal range compared to other eucalypts, from near sea level up to 3000m.
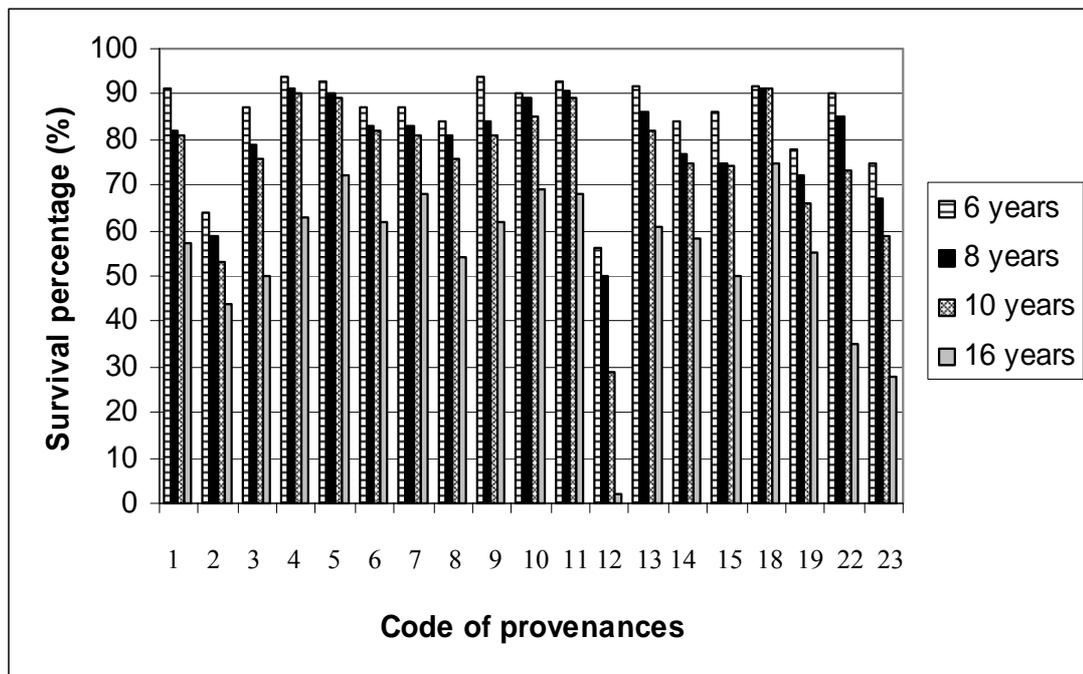

Figure 12 Survival percentages of Timor Mountain Gum at different ages in provenance trials at Lad Krating Plantation, Chachoengsao

Table 3 Average survival percentages of Timor Mountain Gum at different ages in provenance trials at Lad Krating Plantation, Chachoengsao (DNMRT, significant level at $p<0.05$)

Code of provenances	Survival percentage at different ages/years			
	6	8	10	16
1	91^{ab}	82^{abc}	81^{abc}	57^{cf}
2	64^{de}	59^{ef}	53^{f}	44^{c}
3	87^{abc}	79^{abcd}	76^{bcd}	50^{c}
4	94^{a}	91^{a}	90^{ab}	63^{cf}
5	93^{a}	90^{a}	89^{ab}	72^{f}
6	87^{abc}	83^{abc}	82^{abc}	62^{f}
7	87^{abc}	83^{abc}	81^{abc}	68^{f}
8	84^{abc}	81^{abc}	76^{bcd}	54^{cf}
9	94^{a}	84^{abc}	81^{abc}	62^{f}
10	90^{ab}	89^{ab}	85^{abc}	69^{f}
11	93^{a}	90.5^{a}	89^{ab}	68^{f}
12	56^{e}	50^{f}	29^{g}	2^{ns}
13	92^{ab}	86^{abc}	82^{abc}	61^{f}
14	84^{abc}	77^{abcd}	74.5^{cd}	58^{f}
15	86^{abc}	75^{bcd}	74^{cd}	50^{c}
18	92^{ab}	91^{a}	91^{a}	75^{f}
19	78^{bc}	72^{cd}	66^{de}	55^{cf}
22	90^{ab}	85^{abc}	73^{cd}	35^{c}
23	75^{cd}	67^{de}	59^{ef}	28^{ns}
Mean ± SD	85.11 ± 10.33	79.71 ± 11.16	75.34 ± 15.13	54.37 ± 20.42

Table 4 ANOVA of the survival percentages of Timor Mountain Gum at different
ages in provenance trials at Lad Krating Plantation, Chachoengsao

6 years

Source of variation	df	SS	MS	F
Blocks	3	1026.316	342.1053	4.911*
Provenances	18	7679.158	426.6199	6.214**
Error	54	3761.684	69.6608	

8 years

Source of variation	df	SS	MS	F
Blocks	3	1114.684	371.5614	5.225**
Provenances	18	8962.632	497.924	7.001**
Error	54	3840.316	71.1170	

10 years

Source of variation	df	SS	MS	F
Blocks	3	1730.684	576.8947	8.087**
Provenances	18	1648.411	915.7836	12.837**
Error	54	3852.316	71.3392	

16 years

Source of variation	df	SS	MS	F
Blocks	3	1634.316	544.772	3.927*
Provenances	18	22145.68	1230.316	8.870**
Error	54	7489.684	138.6979	

*   Significant differences at p<0.05
**   Highly significant differences at p<0.01

Previous survival records for this trial are available at age 6, 8 and 10 years old with the most recent data collection carried out in 2004 at 16 years old. Figure 12 indicates that survival rate reduced sequentially over this period of time. Overall survival rate gradually dropped from 85%, 79%, 75% to the recent 54%.

As summarized in Table 3, survival percentages of provenances differed at different ages. Provenances from Mt. Mandiri, Flores (No. 5), Mt. Sirung, Pantar (No. 11) and Lelogama, Timor (No. 18) were the top three provenances with high survival throughout the 16 years. Provenance from Mt. Lewerok, Flores (No. 4) initially also had high survival until the tenth year, but deteriorate thereafter. At 16 years, provenances from Ampui, Alor (No. 10) and Mt. Kerbau (No. 7) emerged as better surviving. Generally, these provenances can be found at areas of 450 to 1300 msl in their natural habitat, and this plantation is within that altitudinal range.

Variation of survival among these provenances may be affected by their susceptibility to termite attacks and damage by wind as observed in the field.

Provenances from Mt. Wulogai, Flores (No.2) and Mt. Mutis, Timor (No. 12) had the lowest survival percentages during the 16 years, and provenances from Mt. Lakaan, Timor (No. 23) later emerge with low survival. These provenances exist between 800 to 2200 msl in their natural habitat. Therefore, altitudinal level of the seed sources is the most likely factor affecting survival. The result here is in tandem with provenance trials of this species elsewhere, where provenances originating from above 1500m altitude perform poorly in the lowland tropics (Faridah Hanum and Maesen, 1997). Furthermore, in this study altitudinal level was positively correlated with provenance (0.324, $p<0.01$), and negatively correlated with survival (-0.457, $p<0.01$). However, altitudinal level does not have significant relationship with other growth characteristics.

Survival percentages were statistically highly significant different ($p<0.01$) between provenances at all ages, while variation between blocks were highly significant at 8 and 10 years ($p<0.01$) and significant at 6 and 16 years ($p<0.05$) (Table 4). Mortality between blocks differed although soil type, site preparation and silvicultural treatments were similar. Adaptation process of each provenance probably affected the survival percentages.

2. <u>Growth Performance</u>

Height

Tree height is used to determine superiority of selected provenances. Average height of all trees tends to increase as trees get older. At 6, 8, 10 to 16 years average height of all trees increased were 18m, 20m, 21m and 25m respectively. Illustrated in Table 5, is the variation of average height between differing provenances and ages. The best height were observed in provenances Lelogama, Timor (No. 18, 20.17m) and Ampui, Alor (No. 10, 20.1m) at age 6; Kalabahi, Alor (No. 9, 23.02m, 23.76m) at age 8 and 10; and Mt. Lewotobi, Flores (No. 6, 28.86m) at age 16. The least performing provenance was from Ililaku, Wetar (No. 22) at all ages with a height of 14.74m at 6 years-old and 22.12m at 16 years-old. These are all lowland provenances (<1200msl), which implies that height is a genetically inherent character.

Table 5 Average height of Timor Mountain Gum at different ages in provenance
trials at Lad Krating Plantation, Chachoengsao
(DNMRT, significant at $p<0.05$)

Code of provenances	Average height (m) at different ages/years			
	6	8	10	16
1	19.11^{abcd}	22.28^{ab}	23.07^{abcd}	26.7^{b}
2	17.31^{def}	18.73^{de}	21.21^{bcde}	23.54^{b}
3	17.64	20.24^{abcde}	20.70^{de}	25.14^{b}
4	18.90^{cdef}	20.39^{abcde}	21.78^{abcde}	27.02^{b}
5	18.57^{abcdef}	20.51^{abcde}	22.45^{abcde}	24.60^{b}
6	19.41^{abc}	22.16^{abc}	23.05^{abcd}	28.86^{ns}
7	19.07^{abcd}	21.97^{abc}	23.48^{ab}	26.03^{b}
8	17.00^{ef}	18.44^{ef}	20.26^{e}	22.74^{b}
9	19.76^{ab}	23.02^{a}	23.76^{a}	27.14^{b}
10	20.10^{a}	21.62^{abcd}	22.22^{abcde}	26.17^{b}
11	19.65^{abc}	22.5^{ab}	22.30^{abcde}	24.73^{b}
13	16.86^{f}	19.3^{cde}	20.85^{cde}	23.46^{b}
14	17.90^{bcdef}	20.24^{ancde}	22.20^{abcde}	25.57^{b}
15	17.85^{bcdef}	21.93^{abc}	22.04^{abcde}	24.74^{b}
18	20.17^{a}	22.11^{abc}	23.26^{abc}	25.99^{b}
19	16.86^{f}	19.84^{bcde}	21.05^{cde}	23.42^{b}
22	14.74^{g}	16.07^{fg}	18.12^{f}	22.12^{ns}
23	16.79^{f}	18.98^{de}	21.78^{abcde}	24.01^{b}
Mean ± SD	18.02 ± 1.62	20.26 ± 2.22	21.58 ± 1.81	25.11 ± 2.85

Table 6   ANOVA of the average height of Timor Mountain Gum at different ages in
provenance trials at Lad Krating Plantation, Chachoengsao

6 years

Source of variation	df	SS	MS	F
Blocks	3	22.4748	7.4916	5.069**
Provenances	18	189.238	10.5132	7.113**
Error	54	79.8125	1.4780	

8 years

Source of variation	df	SS	MS	F
Blocks	3	15.6132	5.2044	1.704^{ns}
Provenances	18	353.013	19.6118	6.422**
Error	54	164.9128	3.0539	

10 years

Source of variation	df	SS	MS	F
Blocks	3	19.8257	6.6019	3.220*
Provenances	18	235.1498	13.0639	6.371**
Error	54	110.7229	2.0504	

16 years

Source of variation	df	SS	MS	F
Blocks	3	138.2667	46.0889	10.8197**
Provenances	17	215.7117	12.6889	2.9788**
Error	51	217.2454	4.2597	

ns   Non-significant (p>0.05)
*   Significant differences at p<0.05
**   Highly significant differences at p<0.01
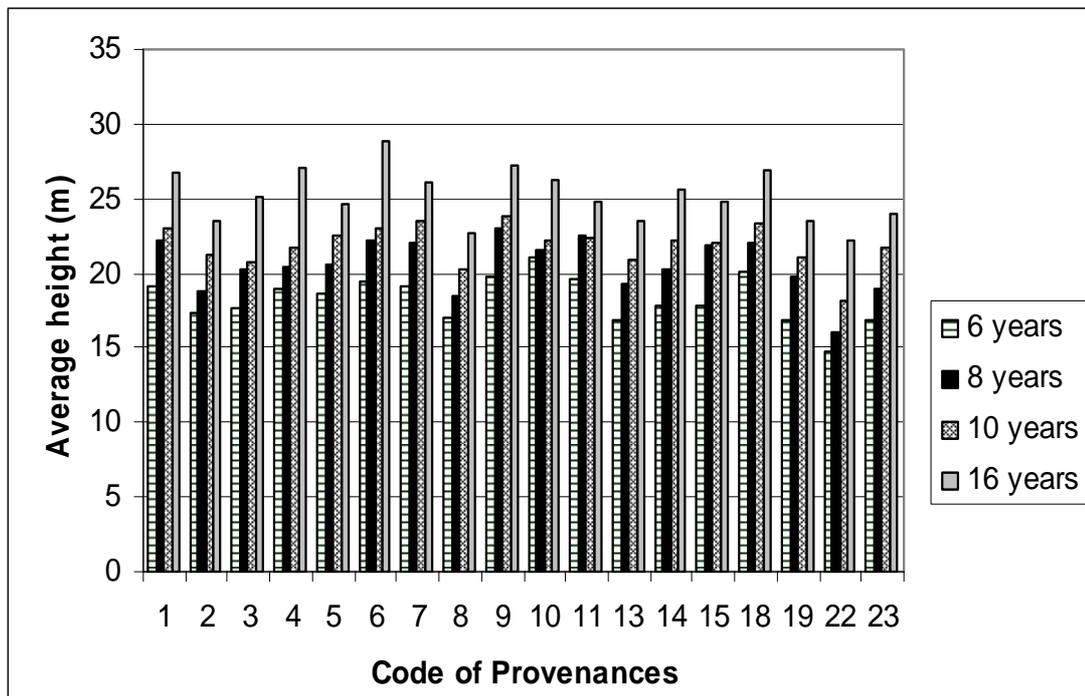
Figure 13   Average height of Timor Mountain Gum at different ages in provenance
             trials at Lad Krating Plantation, Chachoengsao

It was found that variation of average height performance between provenances were statistically highly significant (p<0.01) at all the ages. Meanwhile, variation of average height performance between blocks were highly significant (p<0.01) at age 6 and 16 years, significant at 10 years (p<0.05) and insignificant at 8 years.   This represents the variation sources are genetically linked within the provenances or seed sources, indicative of their growth superiority.   Micro-environment in the blocks also affects tree height development during the early years and maturity level signifying their adaptability to the local condition such as soil and climate (Table 6).

Figure 13 illustrates that Timor Mountain Gum is a species that can achieve considerable height growth during the initial years. During the first 6 years, average height was at 18m. But, this rate of height increment was not repeated in subsequent years. The next 10 years (at 16 years of age) average height increment was only 7m. Total height is indicative of the length of clear bole, and hence has an important economic implication. Correlation is positively high between total height and length of clear bole (0.774, p<0.01).

Diameter at breast height (DBH)

Diameter is the character used to determine tree growth, setting of rotation age, and importantly used as an indicator for genetical selection or thinning. As with the previous growth parameter, average DBH increased with age. These increases were from 16.34cm, 17.74cm, 18.99cm and 23.57cm in sequence from age 6, 8, 10 and 16 years. The best performing provenance at all ages was from Mt. Lewotobi, Flores (No. 6) with a DBH of 18.10cm at 6 years-old and 26.84cm at 16-years old. The least performing provenances were from Kalabahi, Alor at 6 years (14.74cm), Mt. Boleng, Flores (No. 8) at 8 years (16.16cm) and 10 years (17.39cm) of age. At 16 years-old provenance from Mt. Mandiri, Flores (No. 5) was the least performer with a DBH of 18.39cm (Table7).

The variation of average DBH were statistically highly significant ($p<0.01$) between provenances at all ages except at 16 years, which was significantly different ($p<0.05$). While, variation of average DBH were statistically insignificant between blocks at age 6, 8, and 10 but appeared highly significant ($p<0.01$) at age 16 years-old (Table 8). Similarly, this species also achieved the highest rate of average DBH increment during initial growth periods (Figure 14). Average DBH was 16.34cm at 6 years old. Average DBH increment was reduced to 7.23cm for the next 10 years. The rate of DBH increment was slightly lower than that of height increment.
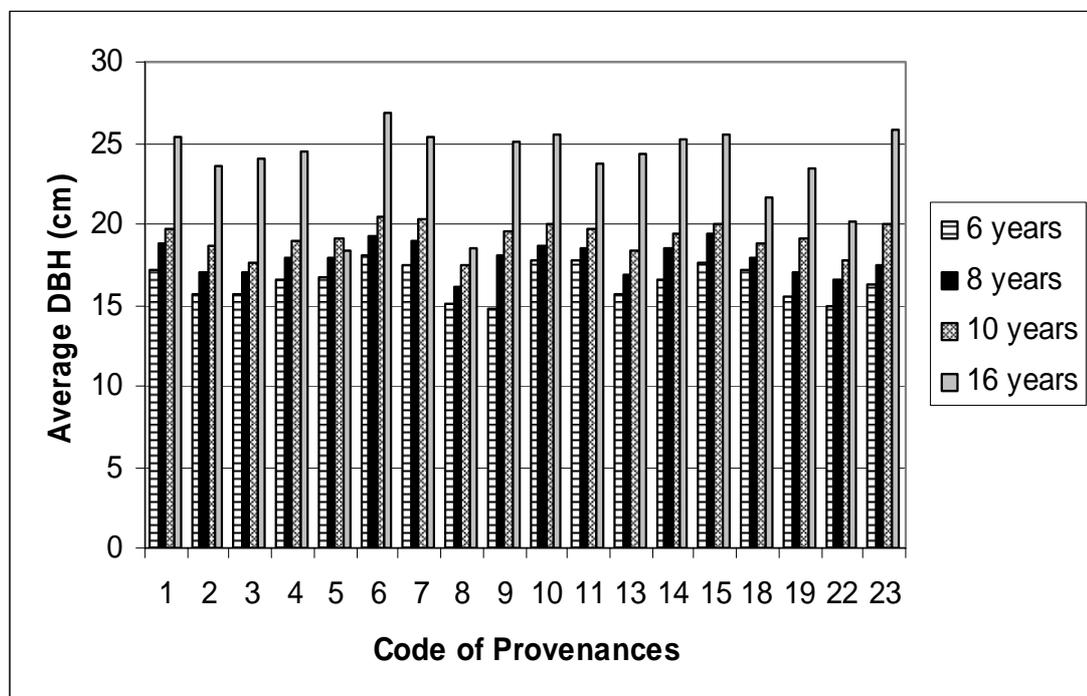

Figure 14 Average DBH of Timor Mountain Gum at different ages in provenance
trials at Lad Krating Plantation, Chachoengsao

Table 7 Average DBH of Timor Mountain Gum at different ages in provenance trials
at Lad Krating Plantation, Chachoengsao
(DNMRT, significant at $p<0.05$)

Code of provenances	Average DBH (cm) at different ages/years			
	6	8	10	16
1	17.18^{abcd}	18.87^{ab}	19.72^{abc}	25.37^{ns}
2	15.63^{bcde}	17.08^{cdef}	18.68^{bcde}	23.57^{ns}
3	15.64^{bcde}	16.98^{cdef}	17.60^{de}	24.05^{ns}
4	16.56^{abcde}	17.88^{abcde}	18.92^{abcde}	24.44^{ns}
5	16.78^{abcd}	17.95^{abcde}	19.12^{abcd}	18.39^{ns}
6	18.10^{a}	19.29^{a}	20.48^{a}	26.84^{ns}
7	17.40^{abc}	19.01^{ab}	20.27^{ab}	25.34^{ns}
8	15.11^{cde}	16.16^{fg}	17.39^{ef}	18.50^{ns}
9	14.74^{de}	18.11^{abcde}	19.54^{abc}	25.03^{ns}
10	17.83^{ab}	18.68^{ab}	19.98^{abc}	25.49^{ns}
11	17.76^{ab}	18.55^{abc}	19.68^{abc}	23.75^{ns}
13	15.60^{bcde}	16.81^{ef}	18.41^{cde}	24.26^{ns}
14	16.53^{abcde}	18.53^{abcd}	19.40^{abc}	25.28^{ns}
15	17.65^{ab}	19.40^{a}	20.01^{abc}	25.51^{ns}
18	17.11^{abcd}	17.93^{abcde}	18.88^{abcde}	19.25^{ns}
19	15.50^{bcde}	16.95^{def}	19.06^{abcd}	23.37^{ns}
22	14.92^{de}	16.53^{ef}	17.70^{de}	20.09^{ns}
23	16.23^{abcde}	17.46^{bcdef}	19.95^{abc}	25.8^{ns}
Mean ± SD	16.34 ± 1.17	17.74 ± 1.17	18.99 ± 1.14	23.57 ± 4.88

Table 8 ANOVA of the average DBH of Timor Mountain Gum at different ages in provenance trials at Lad Krating Plantation, Chachoengsao

6 years

Source of variation	df	SS	MS	F
Blocks	3	7.5480	2.5160	1.206^{ns}
Provenance	18	99.3175	5.5176	2.645**
Error	54	112.6323	2.0858	

8 years

Source of variation	df	SS	MS	F
Blocks	3	6.0625	2.0208	2.211^{ns}
Provenances	18	98.9643	5.4980	6.014**
Error	54	49.3641	0.9141	

10 years

Source of variation	df	SS	MS	F
Blocks	3	5.4068	1.8023	1.850^{ns}
Provenances	18	93.8852	5.2158	5.353**
Error	54	52.6172	0.9744	

16 years

Source of variation	df	SS	MS	F
Blocks	3	332.6044	110.8681	7.2943**
Provenances	17	417.2904	24.5465	1.6150*
Error	51	775.1613	15. 1992	

^{ns} Non-significant (p>0.05)
* Significant differences at p<0.05
** Highly significant differences at p<0.01

Diameter 10 cm above-ground level (D_{10})

The diameter 10cm above-ground level (D10) is useful in evaluating diameter growth and the stem taper of mature tree, which directly affects the potential wood use at the rotation age. Average D10 increases with tree age from 19.59cm, 21.25cm, 22.57cm to 29.79cm at the ages of 6, 8, 10 and 16 years likewise. Provenance Mt. Lewotobi, Flores (No.6) consistently performed well at all ages with an initial and final D10 of 21.10cm and 32.48cm respectively. Additionally, provenances from Ampui, Alor (No.10) performed well at age 6 years, and provenances from Mt. Kerbau, Lomblen (No.7) at ages 8 to 10 years respectively. From age 8 years to 10 years old, the lowest performing provenances were from Mt. Boleng, Flores (No. 8)

and Mt. Wokoh, Flores (No. 3). At age 16 years, provenance Lelogama, Timor (No.18) emerged as the lowest performer with a D10 of 27.1cm (Table 9).

The variation of average D10 between provenances were statistically highly significant at all ages (p<0.01). The variation of average D10 between blocks were statistically highly significant (p<0.01) at 6 years and 16 years, and significant (p<0.05) at 8 years and 10 years (Table 10). The highest rate of average D10 increment was also attained during initial growth periods (Figure 15). Average DBH was 19.59cm at 6 years old. Average D10 increment was reduced to 10.20cm for the next 10 years.
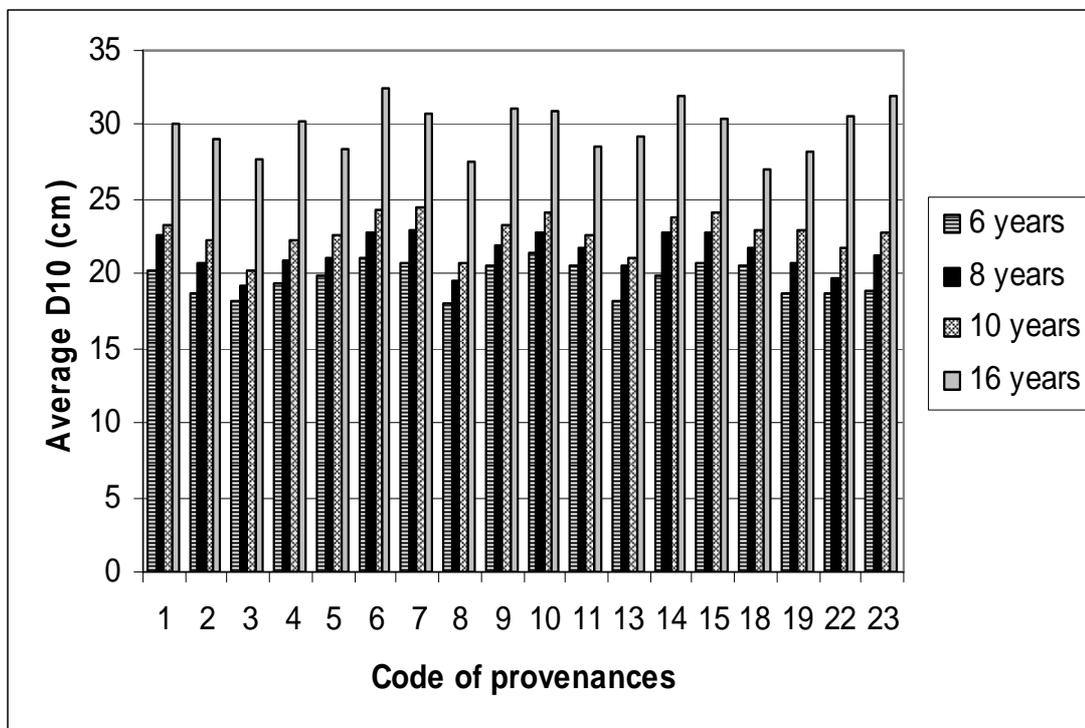
Figure 15 Average D10 of Timor Mountain Gum at different ages in provenance trials at Lad Krating plantation, Chachoengsao

Table 9 Average D10 of Timor Mountain Gum at different ages in provenance trials
at Lad Krating Plantation, Chachoengsao
(DNMRT, significant at $p<0.05$)

Code of provenances	Average D10 (cm) at different ages/years			
	6	8	10	16
1	20.20^{abc}	22.55^{abc}	23.35^{abc}	30.06^{ce}
2	18.63^{cdef}	20.69^{cdef}	22.19^{bcde}	29.06^{c}
3	18.23^{def}	19.26^{fg}	20.23^{fg}	27.75^{c}
4	19.42^{bcde}	20.85^{bcdef}	22.18^{bcde}	30.23^{ce}
5	19.83^{abcd}	21.14^{abcde}	22.65^{abcd}	28.45^{c}
6	21.10^{ab}	22.77^{a}	24.25^{a}	32.48^{e}
7	20.78^{ab}	22.94^{a}	24.50^{a}	30.72^{ce}
8	18.00^{ef}	19.59^{efg}	20.77^{eg}	27.58^{ns}
9	20.53^{ab}	21.92^{abcd}	23.29^{abc}	31.14^{ce}
10	21.46^{a}	22.70^{ab}	24.13^{a}	30.89^{ce}
11	20.60^{ab}	21.76^{abcd}	22.63^{abcd}	28.50^{c}
13	18.24^{def}	20.53^{def}	21.07^{defg}	29.14^{ce}
14	19.88^{abcd}	22.71^{ab}	23.77^{ab}	32.01^{e}
15	20.70^{ab}	22.70^{a}	24.05^{ab}	30.41^{ce}
18	20.48^{ab}	21.75^{abcd}	22.99^{abc}	27.10^{ns}
19	18.67^{cdef}	20.68^{cdef}	22.91^{ab}	28.23^{c}
22	18.64^{cdef}	19.72^{efg}	21.82^{cdef}	30.57^{ce}
23	18.84^{bcde}	21.24^{abcde}	22.74^{abcd}	31.91^{e}
Mean ± SD	19.59 ± 1.21	21.25 ± 1.86	22.57 ± 1.48	29.79 ± 2.37

Table 10   ANOVA of the average D10 of Timor Mountain Gum at different ages in
provenance trials at Lad Krating Plantation, Chachoengsao

6 years

Source of variation	df	SS	MS	F
Blocks	3	13.8515	4.6172	4.222**
Provenances	18	102.9975	5.7221	5.232**
Error	54	59.0551	1.0936	

8 years

Source of variation	df	SS	MS	F
Blocks	3	10.9449	3.6483	2.872*
Provenances	18	135.3446	7.5191	5.919**
Error	54	68.6028	1.2704	

10 years

Source of variation	df	SS	MS	F
Blocks	3	12.7322	4.2441	3.208*
Provenances	18	144.0988	8.0055	6.051**
Error	54	71.4472	1.3231	

16 years

Source of variation	df	SS	MS	F
Blocks	3	80.1558	26.7186	9.7331**
Provenances	17	181.9363	10.7021	3.8986**
Error	51	140.001	2.7451	

*   Significant differences at $p < 0.05$
**   Highly significant differences at $p < 0.01$

3. Stem forms

Genetic stem straightness is the major determinant of wood quality and of all wood products. Tree straightness has a moderately strong inheritance pattern, and there is a lot of variability for these traits (Zobel and Jett, 1995).

Figure 16 indicated that Timor Mountain Gum in the provenance trials only had less than 20% of straight stem trees. Whereas, 25.5% (276 trees) had curved stem, 21.9% (237 trees) had twisted stem, and the remaining percentage were made up of trees that were leaning, two-stems, two-tops, nested and short-bole. Stem forms were very variable within provenance as shown in Figure 17, and showed statistical highly significant difference (p<0.01). But, analysis of variance of stem forms were insignificant (p>0.05) between provenances (Table 11). However, provenances in the field observation showed some or weak tendencies of stem form. Generally, these are the provenances that show their tendencies towards a particular stem form: provenance 5 (curved), provenance 6 (straight), provenance 7 (twisted), provenance 8 (curved), provenance 10 (twisted), provenance 14 (curved), and provenance 18 (curved).

Provenance variation in wood properties can be related to differences in growth phenology and this is exemplified by provenance transfer. For example, *Pinus sylvestris* L. provenances transferred a few degrees southwards have a high survival and yield but low stem wood production (Stahl, 1998). Stem straightness is moderately heritable, as demonstrated in *Pinus taeda* L., where inheritance was relatively high for crook, but sweep was moderately weakly inherited (Ehrenberg, 1970).

4. Bark types and thickness

Bark thickness is the distance between the cambium and the region of convex closure outside the bark. The potential value of bark is related to the huge volume. Bark characteristics tends to differ between species, provenances, and in individual trees.

Figure 18 illustrates that in the provenance trials of Timor Mountain Gum, 23.6% (257 trees) had tessellated bark, 22% (241 trees) shed their bark in strips, 16.8% (182 trees) shed their bark in ribbons, 14.8% had fissured bark, and the remaining percentage showed differing bark types. There were only 23% of rough barks (4, 9, 10, 11) compared to the rest of the smooth barks. As shown in Figure 19, each provenance had varying bark types, some showing tendencies towards a particular bark type. For example, provenance 1 tended to shed its bark in ribbons, provenance 5 and 6 tended to shed bark in strips, and provenance 23 tended to develop fissured bark. Bark types were not significantly different (p>0.05) among provenances, but highly significant different (p<0.01) within the provenances (Table 11). Appendix 1 contains graphical illustration and detailed description of the bark types mentioned here.
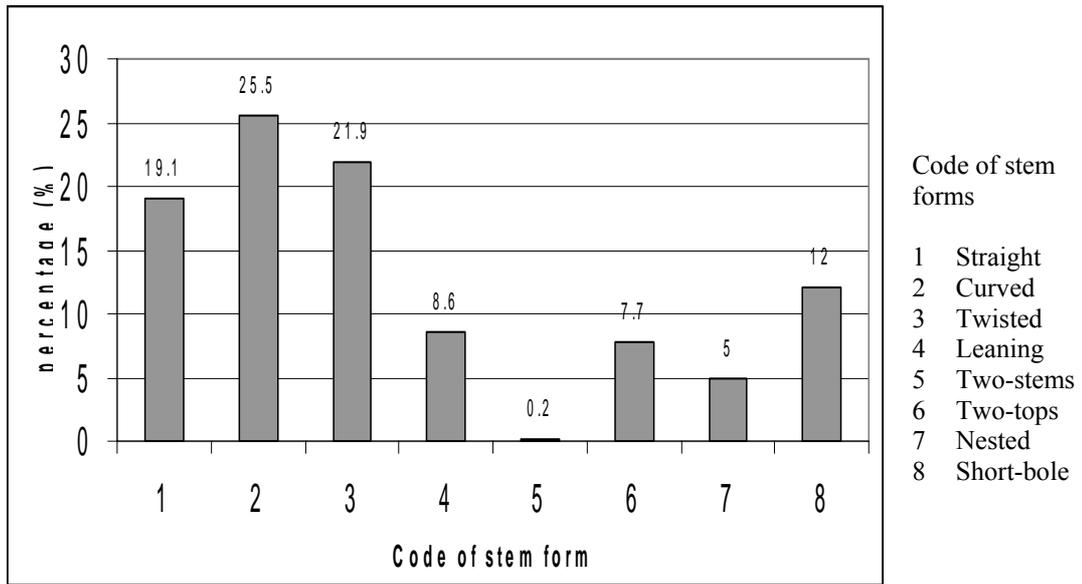
Figure 16 The overall percentages of stem forms distribution of Timor Mountain
Gum in provenance trials at Lad Krating Plantation, Chachoengsao

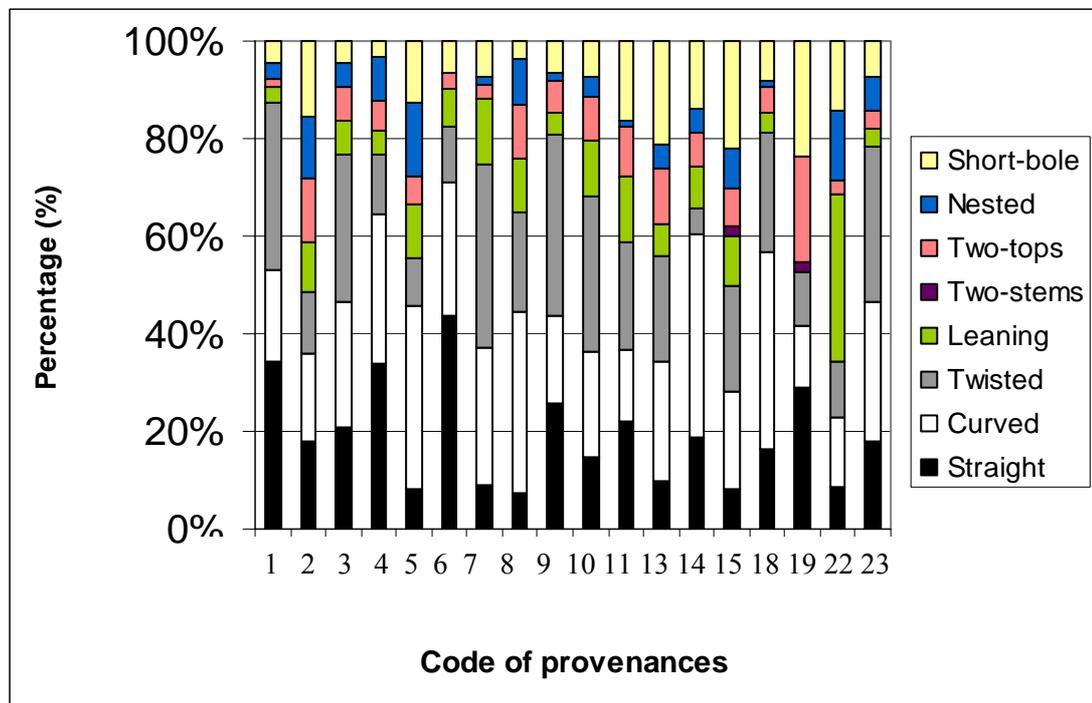Figure 17 The percentages of stem forms distribution within the provenances of
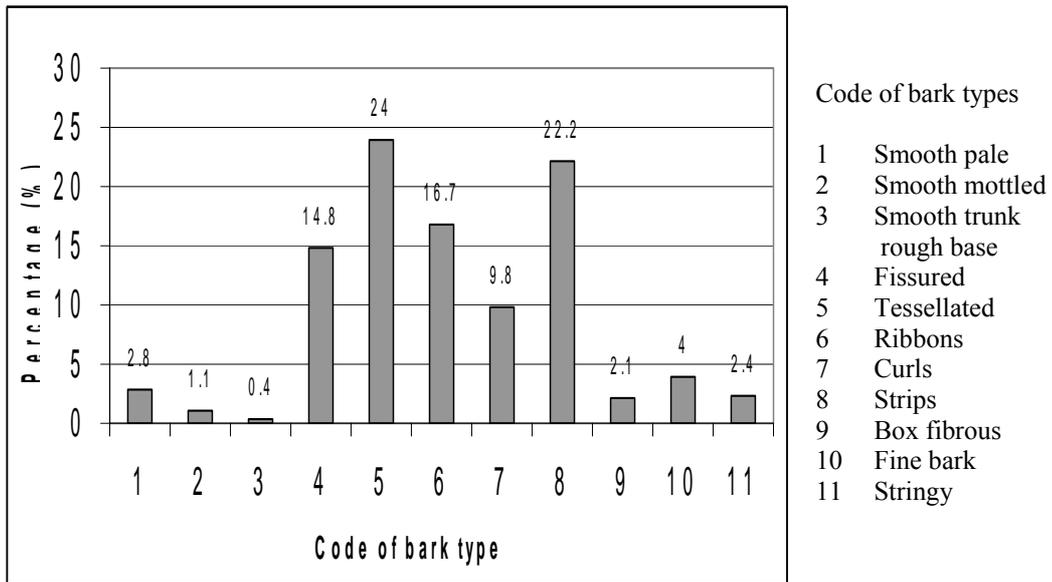Timor Mountain Gum at Lad Krating Plantation, Chachoengsao

Figure 18 The overall percentages of bark type distribution of Timor Mountain Gum
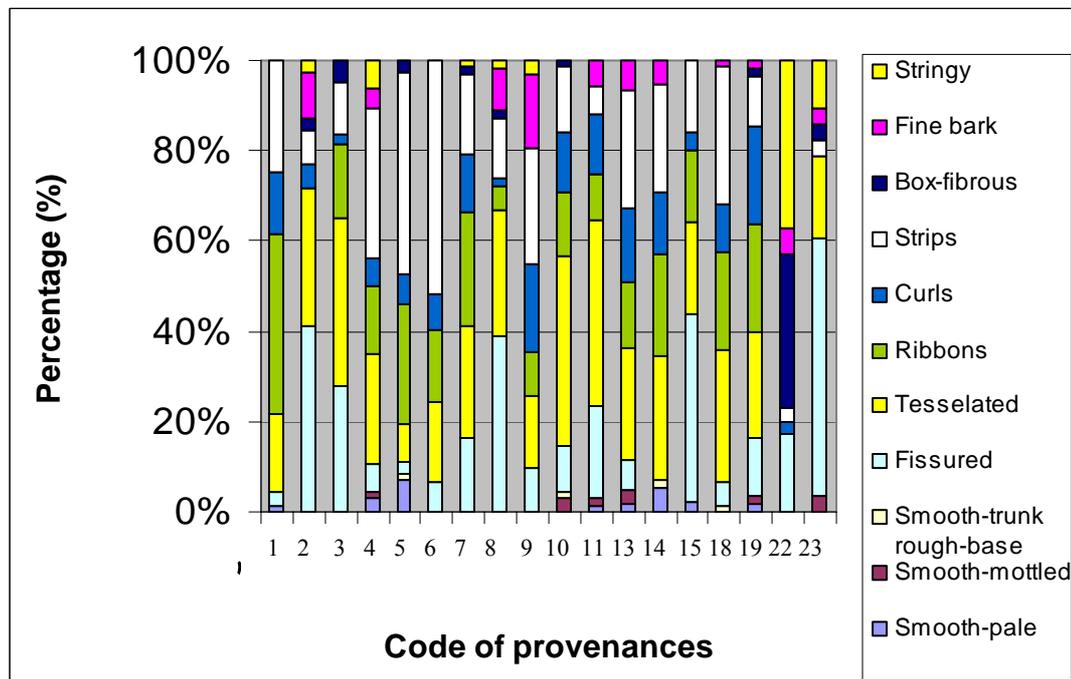in provenance trials at Lad Krating Plantation, Chachoengsao

Figure 19 The percentages of bark types within provenances of Timor Mountain
Gum at Lad Krating Plantation, Chachoengsao
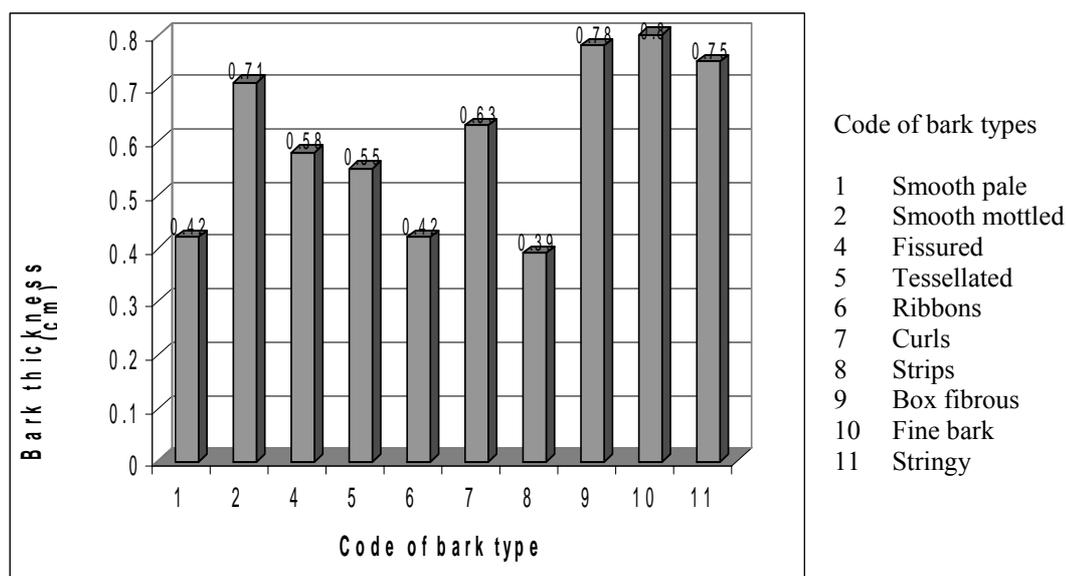
Figure 20 Average thickness of each bark type of Timor Mountain Gum in provenance trials at Lad Krating Plantation, Chachoengsao

Table 11 ANOVA of the stem forms and bark types of Timor Mountain Gum in 16 years-old provenance trials at Lad Krating Plantation, Chachoengsao

Stem forms

Source of variation	df	SS	MS	F
Within provenances	7	3294.639	470.663	19.445**
Between provenances	17	370.75	21.809	0.901[ns]
Error	119	2880.361	24.205	

Bark types

Source of variation	df	SS	MS	F
Within provenances	10	4904.141	490.414	18.526**
Between provenances	17	277.556	16.327	0.617[ns]
Error	170	4500.222	26.472	

ns   Non-significant ($p > 0.05$)
**   Highly significant differences at $p < 0.01$

In the *Eucalyptus*, bark types are generally described as smooth barks and rough barks. Smooth barks shed the dead layer of the bark in large slabs, in ribbons, or in small flakes. The exposed new layer of living bark, which is relatively smooth and brightly colored, can fade with weathering. As the dead bark comes off in pieces at differing times of the year, the trunk becomes mottled. The rough barks are generally categorized as ironbarks, tessellated, stringy and fibrous, box, imperfectly-shed, compacted and loose basal slabs.

Bark thickness ranged from 0.2cm to 1.2cm for all the bark types. As expected, most of the rough barks (bark types 9, 10, 11 – fibrous and subfibrous) had higher average bark thickness with the exception of bark type 4 (ironbark). Meanwhile, the smooth barks showed varying degree of bark thickness, but had lower average bark thickness than the rough barks mentioned above (Figure 20).

Most studies confirmed that bark thickness increases with the size of the trunk or older branches. Gill and Ashton (1968) also explained somewhat similar patterns of bark thickness of Victorian eucalypts as in Timor Mountain Gum here. The fibrous bark of *E. obliqua* is thicker than the subfibrous bark of *E. radiata*, and this in turn is thicker than the decorticating bark of *E. cypellocarpa* for the same girth of trunk or branch.

Bark thickness is under considerable amount of genetic control for many species including Timor Mountain Gum. Wei and Borralho (1997) found that heritability in a progeny trial in South East China for bark thickness and relative bark thickness were high at 0.45 and 0.40 respectively. Furthermore, site interaction was unimportant for wood basic density, bark thickness, and relative bark thickness.

The bark represents a significant volume and can affect the volume of usable wood. Thus, Hamilton and Chikumbo (1997) detailed the process of developing the bark thickness models. The models are non-linear and show upper stem double bark thickness as an exponential decay from double bark thickness at breast height. The models have the flexibility to represent variations in bark thickness patterns found in northeastern eucalypts in Australia and provide a better fit than alternative published models.

Thick bark has been shown to insulate meristems and bud primordial from lethally high temperature associated with fire, although the effectiveness depends on the intensity and duration of a fire, on the diameter of the trunk or branch, on the position of bud primordial within the bark or cambium and on the bark quality (e.g. thermal conductivity) and moisture. Thick bark may also provide protection of vital tissues against attack by pathogens, herbivores, frost or drought. It should be realized, however, that the structure and biochemistry of the bark (e.g. suberia in cork, lignin, tannins, other phenols, gums, and resins) are often important components of bark defense as well (Cornelissen *et al.*, 2003).

The study on the mechanical role of bark in several temperate species was reported by Niklas (1999). He found that the bark contributed significantly to the ability of stem segments differing in age to resist bending forces, but its contribution was age-dependent and differed among species. On average, the stiffness of the bark was 50% of the wood.

Assessing bark types is the hardest part of identifying *Eucalyptus*. Therefore, because there are so many different types of rough bark, defined by their texture, color and persistence on the trunk, and because of the variability and imprecision of the descriptive terms, is a feature of only medium reliability for identification purposes (Brooker *et al.*, 2002).

5. Leaf characteristics

The variation of leaf characteristics mentioned here are leaf area, length, maximum width and stomata density, which were compared at 10 years and 16 years. The characteristics of leaves are strongly influenced by environmental factors, but their basic form is genetically controlled (Humphries & Wheeler, 1963). Appendix 2 illustrates the leaf morphology of Timor Mountain Gum provenances at Lad Krating Plantation.

Leaf area

At 10 years, average leaf area ranged from $27.59 cm^2$ (Ermera, Timor; 19) to $46.15 cm^2$ (Mt. Sirung, Pantar; 11). Overall mean of average leaf area at this age was $35.81 cm^2$. At age 16 years, the ranged of average leaf area was wider, between $28.39 cm^2$ (Lelogama, Timor, 18) and $52.23 cm^2$ (Remexio, Timor; 15). Mean average leaf area was slightly higher at $39.86 cm^2$ (Table12).

At 10 years of age, the differences of the average leaf area were statistically highly significant between provenances of Timor Mountain Gum ($p<0.01$), but insignificant between blocks ($p>0.01$). However, at 16 years-old average leaf area were statistically insignificant different ($p>0.05$) for both provenances and blocks (Table 14).

During the past few years, there was significant decrease in annual rainfall at Lad Krating Plantation, which may affect the leaf area. According to van Volkenburgh (1999) leaf expansion is the development behavior that is most vulnerable to inhibition by water deficit and other environmental stresses through complicated regulatory mechanisms of which little is known. Both the rate and extent of leaf expansion dictate the size and shape of a plant canopy and consequently the behavior of that plant in its environment. Tunstall (2005) found that eucalypt communities tend to use water conservatively and hence limit the period and severity of water stress. Leaves dehisce following drought to conserve water, but this reduces

potential for growth after rain. Its slow uptake of water allows considerable loss of water to the eucalypt through direct evaporation from the soil and its use by other plant species.

Table 12　Mean average of the leaf area and leaf length of Timor Mountain Gum in provenance trials at Lad Krating Plantation, Chachoengsao (DNMRT, significant at $p<0.05$)

Code of provenance	Leaf area (cm^2)		Leaf length (cm)	
	10 years	16 years	10 years	16 years
1	32.18^{defg}	36.77^{ac}	13.14^{bcd}	11.55^{ns}
2	38.22^{abcde}	39.34^{acd}	17.57^{a}	13.06^{d}
3	38.56^{abcde}	35.95^{ac}	15.85^{ab}	11.14^{ns}
4	35.69^{bcdefg}	44.87^{cd}	15.19^{abc}	13.99^{d}
5	33.81^{cdefg}	36.20^{ac}	14.55^{bcd}	13.81^{d}
6	34.81^{bcdefg}	38.03^{acd}	14.85^{abcd}	13.58^{d}
7	30.79^{efg}	34.86^{ac}	12.9^{cd}	12.25^{ns}
8	43.07^{ab}	48.69^{d}	15.14^{abcd}	14.67^{d}
9	41.58^{abc}	37.22^{ac}	14.54^{bcd}	12.48^{d}
10	36.45^{bcdef}	36.36^{ac}	14.73^{bcd}	13.06^{d}
11	46.15^{a}	45.93^{cd}	15.91^{ab}	13.39^{d}
13	39.99^{abcd}	50.42^{ns}	14.71^{bcd}	13.44^{d}
14	33.42^{cdefg}	34.42^{a}	13.95^{bcd}	13.11^{d}
15	30.88^{efg}	52.23^{ns}	12.85^{cd}	12.85^{d}
18	28.64^{fg}	28.39^{a}	13.07^{bcd}	12.95^{d}
19	27.59^{g}	31.54^{a}	13.62^{bcd}	12.15^{ns}
22	33.00^{cdefg}	43.04^{cd}	12.26^{d}	12.88^{d}
23	39.15^{abcde}	43.12^{cd}	13.43^{bcd}	12.57^{d}
Mean ± SD	35.81 ± 4.92	39.86 ± 10.99	14.44 ± 1.33	12.94 ± 1.93

Table 13   Average leaf maximum width and stomata density of Timor Mountain
Gum in provenance trials at Lad Krating Plantation, Chachoengsao
(DNMRT, significant at $p<0.05$)

Code of provenance	Maximum width of leaf (cm)		Stomata density/mm^2	
	10 years	16 years	10 years	16 years
1	4.10^{cdef}	5.24^{ade}	549.92	512.25^{ns}
2	4.14^{cdef}	5.08^{a}	620.32	370.62^{ns}
3	4.18^{abcdef}	4.96^{a}	514.96	330.62^{ns}
4	3.97^{ef}	5.65^{de}	523.28	385.25^{ns}
5	3.94^{ef}	4.48^{a}	494.16	249.37^{a}
6	4.20^{abcdef}	4.83^{a}	499.68	316.75^{ab}
7	4.03^{def}	4.87^{a}	623.68	277.37^{ab}
8	4.70^{a}	5.79^{de}	500.64	370.00^{ns}
9	4.71^{a}	5.13^{ad}	597.20	311.12^{ab}
10	4.05^{cdef}	6.69^{e}	568.08	348.62^{ns}
11	4.64^{ab}	5.47^{ade}	396.12	309.50^{ab}
13	4.59^{abc}	6.07^{de}	503.36	353.62^{ns}
14	3.97^{ef}	4.36^{a}	494.16	325.88^{ab}
15	3.93^{ef}	6.62^{de}	557.20	370.75^{ns}
18	3.77^{f}	3.96^{a}	516.32	357.50^{ns}
19	3.66^{f}	4.37^{a}	508.56	361.00^{ns}
22	4.40^{abcde}	5.67^{de}	547.12	345.75^{ns}
23	4.56^{abcd}	5.36^{ade}	543.12	502.12^{ns}
Mean ± SD	4.22 ± 0.33	5.26 ± 1.42	534.69 ± 54.29	355.45 ± 91.28

While, Warren *et al.* (2005) found that Red Iron Bark (*E. sideroxylon* subsp. tricarpa) grown in a common garden experiment had a significant genetic variation in leaf morphology and physiology for most traits, but the variation was unrelated to the rainfall at the site of seed collection.

Table 14   ANOVA of the leaf characteristics of Timor Mountain Gum in provenance
trials at Lad Krating Plantation, Chachoengsao

Leaf area

Source of variation	df	SS	MS	F
Blocks	3	945.424	315.141	3.97^{ns}
Provenances	17	2967.453	174.56	2.20^{ns}
Error	51	4042.764	79.27	

Leaf length

Source of variation	df	SS	MS	F
Blocks	3	5.117	1.706	0.545^{ns}
Provenances	17	49.386	2.905	0.928^{ns}
Error	51	159.571	3.129	

Maximum width

Source of variation	df	SS	MS	F
Blocks	3	3.471	1.157	2.0875^{ns}
Provenances	17	38.309	2.253	1.072^{ns}
Error	51	55.054	1.079	

Stomata density

Source of variation	df	SS	MS	F
Provenances	17	578042.3	34002.49	6.984*

ns   Non-significant (p>0.05)
*   Significant differences at p<0.05

Leaf length

At 10 years-old, leaf length ranged from 12.26cm (Illilaku, Wetar; 22) to 17.57cm (Mt. Wulogai, Flores; 2), and had a mean average leaf length of 14.44cm. This figure reduced slightly at 16 years-old to 12.94cm. The range of leaf length also shifted between 11.14cm (Mt. Wokoh, Flores; 3) and 14.67cm (Mt. Boleng, Flores; 8) (Table12). At the age of 10 years, there were highly significant differences of leaf length (p<0.01) between provenances but differences were insignificant (p>0.05) between the blocks. However at 16 years old, differences between provenances and blocks were insignificant (p>0.05) for this leaf character (Table 14).

Maximum width of leaf

At 10 years-old, the average maximum width of Timor Mountain Gum ranged from 3.66cm (Ermera, Timor; 19) to 4.71cm (Kalabahi, Alor; 9). Mean average maximum width was 4.22cm. That figure slightly rose to 5.26cm at 16 years-old. The range was also wider starting from 3.96cm (Lelogama, Timor; 18) to 6.69cm (Ampui, Alor; 10) (Table 13). At the age of 10 years, the differences of maximum width was highly significant ($p<0.01$) between provenances but differences was insignificant ($p>0.05$) between the blocks. Differences between provenances and blocks were insignificant ($p>0.05$) for this leaf character at 16 years old (Table 14).

Stomata density

Stomata are only present on the abaxial surface of the Timor Mountain Gum leaf. At 10 years-old, stomata density on the abaxial surface of the species ranged from 396.12 (Mt. Sirung, Pantar; 11) to 623.68 stomata/mm^2 (Mt. Kerbau, Lomblen; 7). Mean average stomata density was 534.69 stomata/mm^2. At 16 years, mean average stomata density was 355.45 stomata/mm^2 while the range was from 249.37 (Mt. Mandiri, Flores; 5) to 512.25 stomata/mm^2 (Mt. Egon, Flores; 1) (Table 13). The differences of stomata density was statistically significant ($p<0.05$) between provenances (Table14).

Not all eucalypts have stomata only on the abaxial surface of the leaf. For example, the average density of stomata was 335 and 400 stomata/mm2 on the adaxial and abaxial leaf surface of *E. camaldulensis*. Distribution was uniform in terms of stomatal frequency and size within the leaf. These characteristics were also significantly different among families (Pipatwattanakul, 1996).

Stomata variability is also present on other species. For instance, Atipanumpai (1989) found that size and frequency of stomata were variable on both surfaces of the *Acacia mangium* phyllode. Average stomata density was 385 and 373 stomata/mm^2 on the adaxial and abaxial surfaces respectively. Stomatal frequency increased progressively from the tip to the base consistently on both surfaces of the phyllode. Significant differences in stomatal frequency among provenances and among trees within provenance were found.

6. <u>Performance ranking of Timor Mountain Gum provenances</u>

The scoring system of each trait performance was based on the average values of each provenance, whereby the best ranked provenance would eventually have the lowest score and conversely for the least ranked provenance. Provenance with equal score is given an equal rank.

In this section, the best and least ranking provenances at age 10 years and 16 years old is compared and discussed. At 10 years of age, the three best ranking provenances were No. 7 (Mt. Kerbau, Lomblen), No. 6 (Mt. Lewotobi, Flores) and No. 10 (Ampui, Alor), while the three least ranking provenances were No. 12 (Mt. Mutis, Timor), No. 22 (Ililaku, Wetar) and No. 8 (Mt. Boleng, Flores). Provenance No. 12 had since eliminated itself from the trials due to near total mortality.

At the age of 16 years, the three best ranking provenances were No. 6 (Mt. Lewotobi, Flores), No. 10 (Ampui, Alor) and No. 9 (Kalabahi, Alor), while the three least ranking provenances were No. 8 (Mt. Boleng, Flores), No. 19 (Ermera, Timor) and No. 22 (Ililaku, Wetar). This ranking corresponds with the results at 10 years-old. Timor Mountain Gum reaches maturity at a very early age of three to four years old. The performances of growth characteristics may differ very much when comparison is made between the juvenile and maturity age.

At Lad Kradting Plantation, the provenance trials seem to indicate that some lowland provenances from the island of Flores, Alor, Lomblen performed well overall. These provenances also have a narrow altitudinal range. Those provenances that have the poorest quality of growth characteristics are generally from the higher altitudinal source including one from the island of Wetar.

In Indonesia, two year-old provenance trials showed that a lowland provenance from Kaplung, Wetar Island emerged best (Siagian, 2004). In recent years, Brazil has concentrated genetic improvement work on the progenies that originated from the island of Flores. Scanavaca and Garcia (2003) found that the control group, which are lowland (50-880 amsl) landrace from Camaquã, Casa Brance, Salesópolis and Linhares were superior to the wild introduced material. The best wild origins were Ara Detung, Egon and Ilegele provenances. The best provenances for China were from Mt. Mandiri, Mt. Egon, and Mt. Lewotobi, all from the island of Flores.

Table 15   Scoring of each trait and ranking of Timor Mountain Gum provenances at
Lad Krating Plantation, Chachoengsao

Code of provenances	Score for each trait				Total Score	Rank
	Survival	Total height	DBH	D10		
6	**7**	**1**	**1**	**1**	**10**	**1**
10	3	5	4	5	17	2
9	7	2	8	4	21	3
7	4	6	6	6	22	4
4	6	3	9	9	27	5
14	10	8	7	2	27	5
1	11	4	5	10	30	6
15	14	10	3	8	35	7
11	4	11	12	13	40	8
18	1	7	15	18	41	9
23	18	18	2	3	41	9
13	9	13	10	11	43	10
5	2	12	18	14	46	11
3	14	9	11	16	50	12
2	16	14	13	12	55	13
19	12	15	14	15	56	14
22	17	17	15	7	56	14
8	13	16	17	17	63	15

Remark: best performance (1) to least performance (18) traits

Progeny Tests

    1. <u>Above-ground biomass</u>

        The results presented in Table 16, Table 17, Table 18 represents 25 trees selected for destructive sampling and biomass determination. Table 16 displays the overall means of growth characteristics at the three year-old progenies of Timor Mountain Gum. The mean above-ground biomass was 13.36kg, and ranged between 0.47-42.11kg in accordance to diameter size and height of the tree. This is the period where the species is showing its greatest growth potential. For instance, Xu *et al.* (1996) observed that biomass increment was greatest during the first three years of an *E. grandis x E. urophylla* plantation in Southern China. After that, biomass increment was significantly reduced due to competition. Branch biomass was highest at 2½ years at the time of tree canopy closure. Bark biomass was highest at younger age, and fruit biomass stabilized 2 years after canopy closure.

        Bernardo *et al.* (1998) found that Timor Mountain Gum had greater bole wood accumulation, foliar distribution, which contributed to higher total-tree growth compared to *E. camaldulensis* and *E. pellita* under differing age and spacing treatment in the Cerrado region of Minas Gerais, Brazil. The effect of increased spacing decreased the relative amount of growth allocated to merchantable parts of the trees and increased allocation to the root systems. At 41 months, average whole-tree weight (aboveground + roots) was 54.3 kg.

        Biomass partitioning as shown in Table 17, indicate that biomass matter was greatest in stem wood (10.18kg), followed by the branches (2.17kg), and then the leaves (1.00kg). Paul *et al.* (2003) instead found biomass partitioning of hybrid eucalypts grown on saline soil had the greatest proportion of biomass in the stem wood followed by the leaves. The size of tree determined the proportion of biomass, with the stem wood increasing with tree size, but the proportion of leaves and twigs decreased with size. Periodic assessment of Timor Mountain Gum biomass production in China showed that biomass partitioning differed with age, with the tendency of the stem wood biomass to increase, while leaf biomass reduced steadily with age (Xu *et al.*, 1996). Biomass production and partitioning in eucalypts plantation is influenced by irrigation and fertilization, as reported by Pereira *et al.* (1989) and Pereira and Oshio (1995) of *E. globulus* Labill. stand in Portugal. Water use efficiency was significantly increased by moderate water deficits and varied with genotype. Fertilized trees had 50% more above-ground biomass than controlled trees, and irrigated trees had the highest proportion of stem wood in relation to total standing biomass than non-irrigated trees. The stem wood production per unit of leaf biomass was also higher in both irrigated treatments.

Harvest index

Mean harvest index was 0.73 or 73.21%, and this figure ranged between 0.06-0.87 (Table 16). In this sample a harvest index between 0.70-0.80 was more common.

Table 16   Means and standard deviations of the growth characteristics of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Traits	Mean ± SD
Height (m)	8.89 ± 3.70
Crown diameter (m)	1.82 ± 0.82
DBH (cm)	5.68 ± 2.90
D10 (cm)	6.92 ± 3.12
Crown ratio	0.36 ± 0.16
Harvest index (%)	73.21 ± 16.71
Form quotient	0.68 ± 0.1
Total above-ground biomass (kg)	13.36 ± 13.68

Table 17   Means and standard deviations of the biomass partitioning according to different tree components of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Traits	Stem	Branches	Leaves	Fruits/flowers
Biomass (kg)	10.18 ± 10.14	2.17 ± 2.95	1.00 ± 0.92	0.114 ± 0.03

Table 18   Matrix correlations between above-ground biomass and growth characteristics of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Traits	Height	Clear bole	Crown diameter	DBH	D10
Above-ground biomass	0.817**	0.306	0.828**	0.935**	0.830**

**Correlation is significant at the 0.01 level (2-tailed)

Variation in taper and crown ratio

The variation in taper was determined using the form quotient (difference between diameters at breast height and at 6m). Form quotients ranged between 0.5-0.91, but averaged at 0.68 for all progenies, which indicate that the rate of taper is moderate. A value closer to one suggests that there is less variation in taper. Crown ratio ranged between 0.17-0.99, but averaged at 0.36 (Table 16). Guimares *et al.* (1995) compared the variation in tree taper and volume relationships among provenances of *E. globulus* at six and nine years of age and found that crown ratio, stability coefficient and tree form coefficient were significantly different among provenances. This was also true with the allometric relationships, suggesting the need to use provenance specific volume equations.

The relationship between above-ground biomass and growth characteristics

The relationship between above-ground biomass and growth characteristics are presented in Table 18. It suggests that there was a strong relationship between above-ground biomass with height, crown diameter, DBH and D10 (more than 0.80). These relationships were statistically highly significant. But, there was no meaningful evidence of any association between above-ground biomass and clear bole.

Biomass estimation

Total above-ground biomass can be predicted with the allometric equation given below. The equation was expressed as $Y = a + b\, X$, where Y and X represents total above-ground biomass (in kg) and Dbh^2H (cm, m), respectively.

$$Y = 0.0279X + 0.3579 \qquad\qquad (r^2 = 0.958)$$

This allometric relationship is one of the most commonly used for the prediction of biomass or volume.

2.   Growth characteristics of progenies

Survival percentages

The average survival percentage for Timor Mountain Gum progenies was 97.34% and differed between 70-100%. Only three families had survival percentages lower than 80% and there were families numbered 70, 72 and 73, while the remaining had higher than 80% survival. Although, coefficient of variation was low at 17.28%, at this age the range of survival percentage was quite high (Table 19). Survival variation were statistically highly significant among families ($p<0.01$), but were insignificant among the blocks ($p>0.05$) as shown in Table 20. At this stage, survival is an inherent characteristic. Survival until the end of the rotation will be affected by canopy closure and inter-specific competition, the influence of environment, and other biotic factors.

Survival has rarely been included as a selection trait in any breeding objectives for forest trees (Greaves *et al.,* 1996 cited from Chambers and Borralho, 1996). However, survival may be defined as a measure of adaptability to specific environmental factors, and hence can be defined as distinct traits for different causal factors (e.g. disease, drought, etc.). Chambers and Borralho (1996) found that survival was relatively more important than volume per tree when maximizing volume per hectare, except when survival was above 90%. If trees died in patches rather than being dispersed throughout the stand, survival is likely to become even more important. The success of increasing gains in volume per hectare by including survival in a selection index depends ultimately however on survival being affected by a major factor and the ability to identify them within a given stand.

Table 19   The overall means and standard deviations of the growth characteristics of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Trait	Mean±S.D.	C.V. (%)
Survival (%)	97.34 ± 16.84	17.28
Height (m)	12.09 ± 2.35	19.43
DBH (cm)	10.45 ± 1.91	18.27
D10 (cm)	8.83 ± 1.65	18.68
Crown diameter (m)	1.96 ± 0.60	30.61

Table 20   Average values of the growth characteristics of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Family	Survival (%)	Total height (m)	D10 (cm)	DBH (cm)	Crown diameter (m)
1	97.92 ± 7.22	12.09 ± 2.02	10.35 ± 1.74	8.69 ± 1.49	2.10 ± 0.72
2	100.00 ± 0.00	12.69 ± 2.06	11.04 ± 1.86	9.36 ± 1.41	2.09 ± 0.69
3	100.00 ± 0.00	12.88 ± 1.72	11.22 ± 2.12	9.59 ± 1.79	2.07 ± 0.77
4	100.00 ± 0.00	11.64 ± 2.10	9.99 ± 2.25	8.46 ± 1.85	1.70 ± 0.47
5	91.67 ± 22.19	12.59 ± 2.47	10.75 ± 2.09	9.26 ± 1.91	2.19 ± 0.63
6	95.83 ± 38.19	12.33 ± 2.38	10.63 ± 1.77	9.02 ± 1.50	1.95 ± 0.70
7	100.00 ± 0.00	13.22 ± 2.16	11.17 ± 1.23	9.41 ± 1.08	2.08 ± 0.49
8	100.00 ± 0.00	12.74 ± 2.03	11.67 ± 2.26	9.76 ± 1.80	2.18 ± 0.70
9	89.58 ± 16.71	12.69 ± 1.77	11.44 ± 1.750	9.60 ± 1.40	2.15 ± 0.65
10	100.00 ± 0.00	12.67 ± 1.71	10.94 ± 1.60	9.27 ± 1.45	1.99 ± 0.70
11	89.58 ± 29.11	12.48 ± 2.09	11.03± 1.82	9.63 ± 1.55	2.15 ± 0.59
12	100.00 ± 0.00	13.47 ± 2.14	11.15 ± 1.91	9.52 ± 1.39	1.95 ± 0.52
13	97.92 ± 7.22	12.76 ± 2.61	10.99 ± 1.85	9.31 ± 1.52	1.92 ± 0.48
14	100.00 ± 0.00	11.83 ± 2.38	11.03 ± 2.57	9.43 ± 2.06	2.27 ± 0.65
15	100.00 ± 0.00	11.36 ± 2.24	9.79 ± 1.45	8.02 ± 1.24	1.72 ± 0.39
16	100.00 ± 0.00	12.32 ± 1.87	10.69 ± 1.72	9.14 ± 1.36	2.09 ± 0.44
17	91.67 ± 28.87	11.05 ± 2.53	9.31 ± 1.49	7.73 ± 1.38	1.58 ± 0.40
18	97.92 ± 7.22	12.76 ± 2.06	11.49 ± 1.79	9.68 ± 1.51	2.14 ± 0.63
19	100.00 ± 0.00	11.09 ± 2.38	9.56 ± 1.57	7.85 ± 1.56	1.69 ± 0.47
20	95.83 ± 9.73	12.05 ± 1.75	11.01 ± 1.72	9.12 ± 1.39	2.12 ± 0.67
21	97.92 ± 7.22	11.86 ± 2.29	10.04 ± 1.43	8.44 ± 1.40	1.85 ± 0.40
22	100.00 ± 0.00	11.51 ± 2.12	10.23 ± 1.52	8.44 ± 1.73	1.83 ± 0.60
23	97.92 ± 7.22	11.90 ± 2.13	10.46 ± 1.57	8.81 ± 1.41	1.98 ± 0.57
24	100.00 ± 0.00	12.71 ± 2.38	10.93 ± 1.78	9.10 ± 1.64	2.12 ± 0.45
25	100.00 ± 0.00	12.9 ± 3.16	11.12 ± 1.91	9.30 ± 1.34	2.06 ± 0.62
26	93.75 ± 15.54	12.47 ± 2.06	10.70 ± 2.30	9.11 ± 1.69	2.06 ± 0.58
27	95.83 ± 33.43	10.95 ± 2.16	9.91 ± 1.58	8.17 ± 1.35	1.77 ± 0.511
28	89.58 ± 12.87	12.12 ± 2.67	10.85 ± 2.07	9.10 ± 1.88	2.07 ± 0.66
29	100.00 ± 0.00	11.97 ± 1.80	10.61 ± 1.91	8.95 ± 1.68	2.11 ± 0.68
30	100.00 ± 0.00	11.92 ± 2.20	10.19 ± 1.82	8.72 ± 1.53	1.79 ± 0.46
31	100.00 ± 0.00	12.46 ± 2.06	10.32 ± 1.50	8.87 ± 1.50	1.95 ± 0.63
32	100.00 ± 0.00	12.10 ± 1.54	10.50 ± 1.91	8.85 ± 1.37	1.98 ± 0.55
33	100.00 ± 0.00	11.77 ± 1.92	10.46 ± 1.86	8.72 ± 1.64	1.95 ± 0.52
34	97.92 ± 7.22	12.01 ± 1.56	9.83 ± 1.61	8.47 ± 1.33	1.77 ± 0.63
35	100.00 ± 0.00	12.00 ± 2.38	10.11 ± 2.06	8.49 ± 1.60	1.92 ± 0.64
36	97.92 ± 7.22	11.60 ± 2.26	10.10 ± 1.36	8.49 ± 1.19	1.94 ± 0.47
37	95.83 ± 14.43	12.21 ± 3.18	11.02 ± 2.10	9.35 ± 1.55	2.30 ± 0.80
38	87.50 ± 29.19	12.78 ± 1.84	11.23 ± 1.79	9.42 ± 1.54	2.04 ± 0.46
39	100.00 ± 0.00	12.13 ± 2.74	10.90 ± 1.65	9.26 ± 1.58	2.20 ± 0.68
40	100.00 ± 0.00	11.25 ± 1.89	9.64 ± 1.66	8.19 ± 1.52	1.79 ± 0.50

Table 20   (continued)

Family	Survival (%)	Total height (m)	D10 (cm)	DBH (cm)	Crown diameter (m)
41	100.00 ± 0.00	11.98 ± 2.21	10.07 ± 1.95	8.61 ± 1.85	1.92 ± 0.52
42	100.00 ± 0.00	10.65 ± 2.05	9.36 ± 1.99	8.11 ± 1.90	1.95 ± 0.66
43	97.92 ± 7.22	11.61 ± 2.38	10.03 ± 2.27	8.36 ± 2.09	1.85 ± 0.57
44	100.00 ± 0.00	11.9 ± 2.54	10.03 ± 1.56	8.45 ± 1.47	1.94 ± 0.47
45	100.00 ± 0.00	11.74± 2.92	10.11 ± 1.88	8.78 ± 1.62	1.84 ± 0.52
46	100.00 ± 0.00	11.85 ± 2.24	9.83 ± 2.16	8.49 ± 1.94	1.86 ± 0.62
47	100.00 ± 0.00	12.67 ± 1.75	10.74 ± 1.96	9.16 ± 1.71	2.14 ± 0.68
48	95.83 ± 9.73	13.03 ± 3.24	10.07 ± 1.52	8.69 ± 1.33	1.94 ± 0.50
49	100.00 ± 0.00	12.92 ± 2.21	10.22 ± 1.42	8.73 ± 1.37	2.08 ± 0.61
50	100.00 ± 0.00	11.47 ± 1.89	10.17 ± 1.74	8.57 ± 1.34	1.82 ± 0.56
51	100.00 ± 0.00	11.7 ± 2.01	10.08 ± 1.66	8.60 ± 1.43	1.80 ± 0.46
52	97.92 ± 7.22	11.60 ± 2.63	9.65 ± 1.64	8.09 ± 1.49	1.84 ± 0.52
53	97.92 ± 7.22	11.75 ± 1.83	10.62 ± 1.73	8.87 ± 1.55	1.88 ± 0.50
54	97.92 ± 7.22	12.46 ± 2.39	10.97 ± 2.20	9.26 ± 1.77	2.22 ± 0.63
55	97.92 ± 7.22	12.42 ± 2.21	10.81 ± 1.81	9.21 ± 1.35	1.98 ± 0.61
56	97.92 ± 7.22	12.26 ± 1.73	10.66 ± 2.02	9.03 ± 1.66	2.07 ± 0.47
57	100.00 ± 0.00	12.21 ± 2.21	10.37 ± 1.55	8.85 ± 1.25	1.83 ± 0.45
58	91.67 ± 22.19	10.15 ± 3.12	9.67 ± 2.33	8.16 ± 2.00	2.11 ± 0.74
59	100.00 ± 0.00	11.66 ± 1.85	10.24 ± 1.74	8.77 ± 1.42	1.78 ± 0.56
60	97.92 ± 7.22	12.57 ± 1.54	11.13 ± 1.70	9.49 ± 1.38	2.03 ± 0.49
61	91.67 ± 28.87	12.72 ± 2.18	10.23 ± 1.52	8.56 ± 1.30	1.71 ± 0.36
62	100.00 ± 0.00	12.76 ± 2.32	10.93 ± 1.59	9.43 ± 1.28	1.96 ± 0.60
63	83.33 ± 30.77	10.54 ± 2.03	9.28 ± 1.99	7.92 ± 1.53	1.97 ± 0.86
64	95.83 ± 9.73	11.58 ± 2.47	9.89 ± 1.84	8.33 ± 1.64	1.80 ± 0.47
65	100.00 ± 0.00	12.28 ± 1.78	10.95 ± 2.15	9.29 ± 1.72	1.98 ± 0.53
66	95.83 ± 17.94	11.47 ± 2.19	9.88 ± 1.71	8.15 ± 1.55	1.84 ± 0.54
67	100.00 ± 0.00	12.37 ± 2.42	10.00 ± 1.95	8.43 ± 1.61	1.69 ± 0.55
68	100.00 ± 0.00	12.07 ± 1.70	9.96 ± 1.74	8.38 ± 1.38	1.63 ± 0.54
69	100.00 ± 0.00	12.57 ± 2.53	10.87 ± 1.66	9.20 ± 1.79	2.34 ± 0.86
70	70.83 ± 33.43	11.27 ± 2.12	9.99 ± 2.19	8.51 ± 1.70	1.88 ± 0.59
71	93.75 ± 11.31	11.04 ± 2.10	9.57 ± 1.83	8.07 ± 1.57	1.87 ± 0.58
72	72.92 ± 40.53	11.16 ± 2.34	9.56 ± 2.03	8.09 ± 1.86	1.92 ± 0.80
73	77.08 ± 31.00	8.48 ± 3.10	8.06 ± 2.68	6.67 ± 2.54	1.64 ± 0.65
74	100.00 ± 0.00	12.90 ± 2.63	10.73 ± 1.80	8.94 ± 1.53	1.87 ± 0.51
75	91.67 ± 28.87	13.06 ± 2.56	11.03 ± 1.59	9.21 ± 1.43	2.05 ± 0.48
76	100.00 ± 0.00	12.79 ± 2.64	10.94 ± 1.65	9.41 ± 1.42	1.95 ± 0.47
77	91.67 ± 16.28	12.81 ± 2.36	11.27 ± 1.91	9.65 ± 1.62	2.01 ± 0.55
78	89.58 ± 29.11	12.20 ± 2.51	10.78 ± 1.88	9.18 ± 1.70	2.04 ± 0.53
79	102.08 ± 7.22	12.89 ± 1.97	10.72 ± 1.52	9.16 ± 1.36	2.09 ± 0.59
80	95.83 ± 9.73	12.56 ± 2.06	10.81 ± 1.53	8.98 ± 1.57	2.10 ± 0.74
Total Mean ± SD	97.34 ± 16.84	12.09 ± 2.35	10.45 ± 1.91	8.83 ± 1.65	1.96 ± 0.60

Height

Average total height of Timor Mountain Gum progenies was 12.09m and varied between 8.48m (Family 12) - 13.47m (Family 73) as shown in Table 20. Coefficient of variation was 19.43% (Table 18). Analysis of variance indicates that height variation were statistically highly significant ($p<0.01$) different among families and among blocks (Table 21).

Diameter at breast height (DBH)

On average diameter at breast height (DBH) of the progenies was 8.83cm, and ranged between 6.67m (Family 73) - 9.76m (Family 8) as listed in Table 20. The variation of DBH were statistically highly significant ($p<0.01$) different amongst families and blocks as shown in Table 21.

Diameter 10cm above-ground level (D10)

Diameter at 10cm above ground level had an average of 10.45cm. This growth trait ranged between 8.06cm (Families 73) – 11.67cm (Families 8) as listed on Table 20. The best and least performing families identified here were similar to that of DBH performance. Likewise, the variation of DBH were statistically highly significant ($p<0.01$) different amongst families and blocks (Table 21).

Crown diameter

The average value of crown diameter was 1.96m, and varied from 1.58m (Family 17) – 2.19m (Family 5) as shown in Table 20. Of the entire growth traits, coefficient variation was quite high for crown diameter at 30.61 (Table 19). There were statistically highly significant ($p<0.01$) different variation in crown diameter among families and blocks (Table 21).

Table 21   ANOVA of the growth characteristics of Timor Mountain Gum progenies
          at Lad Krating Plantation, Chachoengsao

Survival percentages

Source of variation	df	SS	MS	F	h^2
Blocks	11	3.187	0.290	2.268^{ns}	
Families	79	66.162	0.837	1.434**	0.303
Residual	869	365.812	0.421		

Total Height

Source of variation	df	SS	MS	F	h^2
Blocks	11	1269.947	115.450	53.872**	
Families	79	623.707	7.895	2.587**	0.613
Residual	869	2658.535	3.052		

DBH

Source of variation	df	SS	MS	F	h^2
Blocks	11	76.775	6.980	6.205**	
Families	79	324.060	4.102	4.417**	0.774
Residual	869	808.860	0.929		

D10

Source of variation	df	SS	MS	F	h^2
Blocks	11	202.722	18.429	12.466**	
Families	79	411.287	5.206	3.844**	0.740
Residual	869	1179.661	1.354		

Crown diameter

Source of variation	df	SS	MS	F	h^2
Blocks	11	39.735	3.612	25.624**	
Families	79	27.038	0.342	2.055**	0.513
Residual	869	145.070	0.167		

Stem form

Source of variation	df	SS	MS	F	h^2
Blocks	11	220.391	20.036	7.448**	
Families	79	439.241	5.560	2.074**	0.518
Residual	869	9804.331	2.680		

ns   Non-significant (p>0.05)
**   Highly significant differences at p<0.01
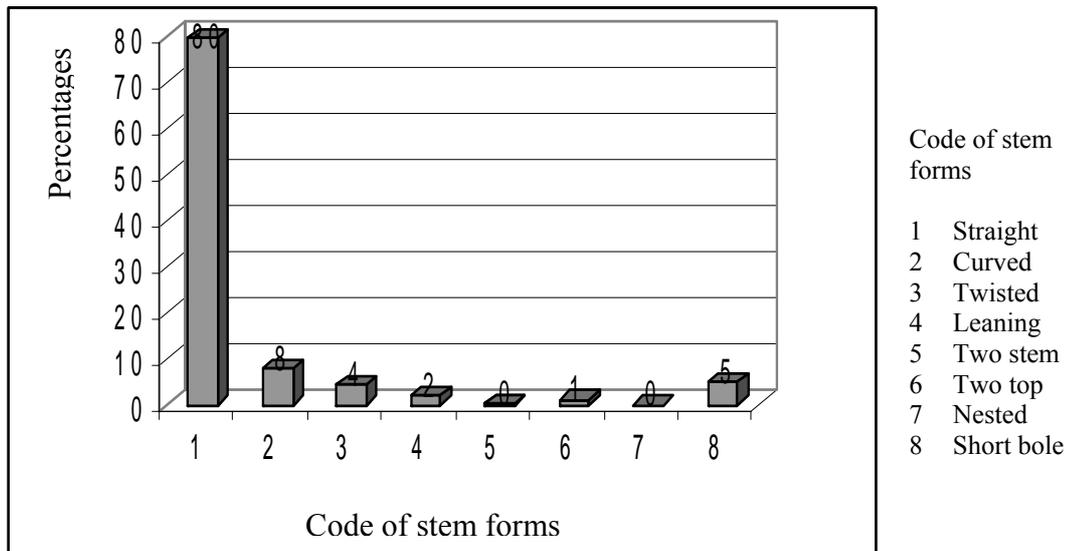
Figure 21   The overall percentages of stem forms in Timor Mountain Gum progenies
at Lad Krating Plantation, Chachoengsao

Stem forms

Figure 21 illustrates the overall percentage of stem forms of the entire
progenies. In this young stand, stem form is not yet pronouncedly varied as the older
stand of the provenance trials. About 80% of the total stand had straight stem; while
the curved, twisted, leaning, nested, and short-bole stem forms comprise of the
remaining 20%; and the two-stems and two-tops stem forms were absent from the
stand. However, as illustrated in Figure 22, the percentages of straight-stem trees
amongst the families were quite varied, between 40% (Family 58) to 96% (Family
62). Analysis of variance for this trait were statistically highly significant (p<0.01)
different between families and blocks (Table 20).

As revealed in a study of 5 year-old *A. mangium* advanced generation seed
orchard in Chachoengsao, Thailand with 90 families had similar distribution of
straight stem forms was somewhat similar with about 82%. However, the percentages
of stem straightness between families were narrower in range, from 71.71-94.31%
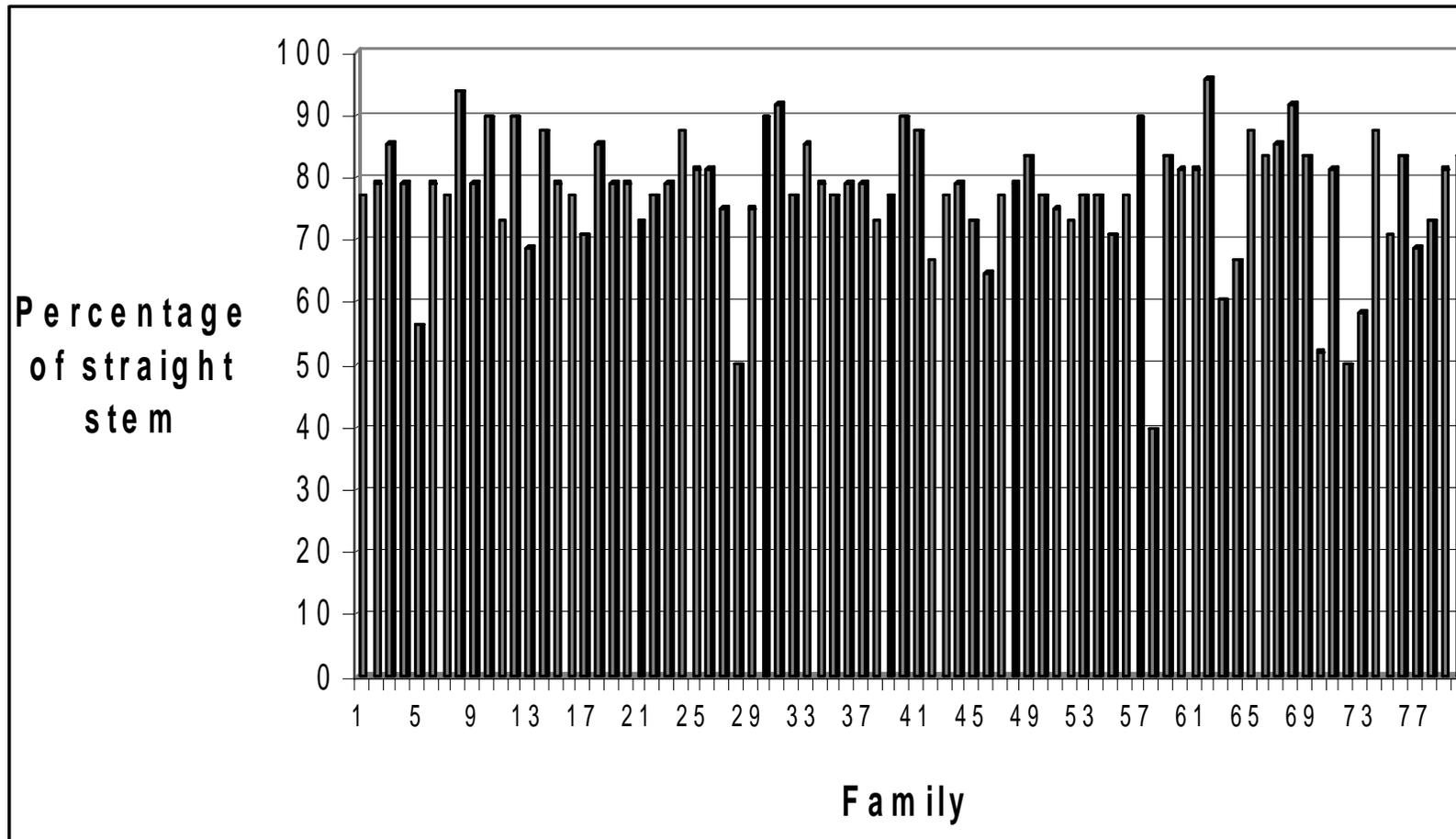(Koy Ra, 2002).

Figure 22   The percentages of straight-stem trees of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Table 22   Matrix of trait-trait correlations between growth characteristics of Timor
Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

	Total height	Clear bole	D10	DBH	Crown diameter
Total height	1	0.724(**)	0.450(**)	0.520(**)	0.051
Clear bole	0.724(**)	1	0.325(**)	0.405(**)	0.183(**)
D10	0.450(**)	0.325(**)	1	0.916(**)	0.507(**)
DBH	0.520(**)	0.405(**)	0.916(**)	1	0.517(**)
Crown diameter	0.051	0.183(**)	0.507(**)	0.517(**)	1

**Correlation is significant at the 0.01 level (2-tailed)

The relationship between growth characteristics

There were strong evidence of relationship among growth characteristics, which were statistically highly significant, such as between DBH and D10 (0.916**) and between total height and clear bole (0.724**). Even though all other growth characteristics had statistically highly significant relationships but correlations were low to moderate (Table 22).

3. Heritability estimates

The narrow sense heritability of some growth traits of Timor Mountain Gum is expressed in Table 21. Heritability was moderately high for all the growth traits with the exception of survival trait. It is essential to note that survival characteristics may not be a heritable character but an influence of environmental factors. The following are the narrow sense heritability of the growth characteristics of Timor Mountain Gum grown at Lad Krating Plantation, Chachoengsao: survival (0.303), total height (0.613), DBH (0.774), D10 (0.740), crown diameter (0.513), and stem forms (0.518). The repercussion of this is that genetical selection can be carried out to allow for genetic gain.

Appendix 3 presents the composition of phenotypic and genotypic value of these growth characteristics. Phenotypic value was more than 80%, but less than 60% for genotypic value for growth characteristics height, D10, crown diameter and stem forms.

Genetic parameters especially those related to growth and wood quality have been estimated for fast-grown plantation eucalypts. These genetic parameters were also assessed and compared among populations, between traits of interest and with tree age.

For example, in a study assessing growth traits and wood density of three year-old Timor Mountain Gum clones in Veracruz, Mexico, heritability increased with age at the individual (0.25 to 0.52) and clone (0.81 to 0.93) mean levels. Wood density showed greater genetic control than growth traits at the ramet level (Hi_2 = 0.69) (Sànchez *et al.*, 2005). Recently introduced material of Timor Mountain Gum from Flores Island to the Southern region of Brazil saw that four year-old progenies showed high heritability (0.446-0.491) for wood basic density (Mourão and de Arruda Veiga, 1994). Most fast-growing species show to a great extent moderate to high heritability for the most important growth traits in the first three years of active growth. This represents some prospects of using early selection to increase volume growth. In a provenance-progeny tests of Timor Mountain Gum, family heritability of each growth trait across two locations in Indonesia were as follows: height (0.331), bole length (0.620), and DBH (0.405) (Nirsatmanto *et al.*, 1996).

Eucalyptus camaldulensis between the ages of 6 months (0.74, 0.63 – height, D10) to 24 months (0.95, 0.83, 0.90 – height, DBH, D10) in Chachoengsao, Thailand showed enhanced heritability with increased ages for all growth traits (Pipatwattanakul, 1996). Flowering was also a strongly inherited characteristic in a 28 month-old *Acacia mangium* seed orchard in Chachoengsao, Thailand with an average heritability value of 0.98 (Atipanumpai, 1989).

In conifers, heritability estimates were generally moderate for diameter ranging from 0.10 (*Pinus caribaea* var *hondurensis*) to 0.29 (*Pinus elliottii*), moderate to good for height ranging from 0.24 for *P. caribaea* var *hondurensis* and the F_1 hybrid to 0.44 for *P. elliottii*, and were weak for stem straightness, ranging from 0.05 (*P. elliottii*) to 0.07 in the F_1 hybrid (Powell and Nickles, 1996).

4.   Performance ranking of Timor Mountain Gum families

The summation and scoring of growth characteristics for the ranking of the overall best performing provenances indicated that the ten best ranking families are numbered 8 (Ermera, Timor), 18 (Mt. Lewotobi, Flores), 7 (Ermera, Timor), 3 (Ampui, Alor), 9 (Mt. Egon, Flores), 77 (Mt. Egon, Flores), 12 (Mt. Sirung, Pantar), 25 (Mt. Mutis, Timor), 11 (Mt. Sirung, Pantar) and 38 (Remexio, Timor). At this stage, the results are rather preliminary because their performance are still competitive and may differ as they mature and adapt to their surrounding. The ranking methods used here are identical with those used for the ranking of Timor Mountain Gum provenances. The result of the ranking of Timor Mountain Gum progenies are shown in Table 23.

Table 23   The scoring of each trait and ranking of Timor Mountain Gum families at
Lad Krating Plantation, Chachoengsao

Family	Provenances	Score					
		Survival	Total Height	D10	DBH	Crown diameter	Total
8	Ermera, Timor	1	13	1	1	7	23
18	Mt. Lewotobi, Flores	2	12	2	2	9	27
7	Ermera, Timor	1	2	8	11	14	36
3	Ampui, Alor	1	8	7	6	15	37
9	Mt. Egon, Flores	6	16	4	5	8	39
77	Mt. Egon, Flores	5	9	5	3	20	42
12	Mt. Sirung, Pantar	1	1	9	7	25	43
25	Mt. Mutis, Timor	1	6	11	15	16	49
11	Mt. Sirung, Pantar	6	21	13	4	8	52
38	Remexio, Timor	7	11	6	10	18	52
2	Ampui, Alor	1	16	12	12	13	54
75	Mt. Egon, Flores	5	3	13	19	17	57
60	Mt. Mandiri, Flores	2	19	10	8	19	58
37	Mt. Wulogai, Flores	3	30	14	13	2	62
69	Mt. Lakaan, Timor	1	19	23	20	1	64
54	Mt. Wokoh, Flores	2	23	17	18	4	64
62	Lelogama, Timor	1	12	20	9	24	66
76	Mt. Egon, Flores	1	10	19	11	25	66
13	Mt. Wasbilla, Pantar	2	12	16	14	27	71
14	Mt. Wasbilla, Pantar	1	46	13	9	3	72
79	-	1	7	29	22	13	72
5	Ampui, Alor	5	18	26	18	6	73
24	Mt. Lewotobi, Flores	1	15	20	27	10	73
10	Mt. Egon, Flores	1	17	19	17	21	75
39	Remexio, Timor	1	32	21	18	5	77
47	Mt. Sirung, Pantar	1	17	27	23	9	77
65	Lelogama, Timor	1	28	18	16	22	85
80	Ililaku, Wetar	3	20	24	30	12	89
20	Mt. Wasbilla, Pantar	3	37	15	25	10	90
55	Mt. Wokoh, Flores	2	24	24	19	22	91
16	Kalabahi, Alor	1	27	31	24	13	96
74	Mt. Egon, Flores	1	6	28	32	29	96
26	Mt. Egon, Flores	4	22	30	26	16	98
49	Mt. Wulogai, Flores	1	5	43	38	14	101
78	Kalabahi, Alor	6	31	25	21	18	101
28	Mt. Kerbau, Lomblen	6	33	22	27	15	103
56	Mt. Wasbilla, Pantar	2	29	32	28	15	106
6	Mt. Lewerok, Flores	3	26	33	29	25	116
29	Mt. Egon, Flores	1	41	35	31	11	119

Table 23   (continued)

Family	Provenances	Score					
		Survival	Total Height	D10	DBH	Crown diameter	Total
48	Mt. Lewotobi, Flores	3	4	49	40	26	122
31	Ermera, Timor	1	23	40	33	25	122
32	Ermera, Timor	1	34	36	34	22	127
1	Mt. Lewerok, Flores	2	35	39	40	12	128
57	Mt. Wasbilla, Pantar	1	30	38	34	33	136
23	Mt. Wasbilla, Pantar	2	43	37	35	22	139
50	Hatuloi, Wetar	1	22	45	43	34	145
53	Mt. Wokoh, Flores	2	48	34	33	28	145
61	Lelogama, Timor	5	14	42	44	40	145
33	Mt. Wokoh, Flores	1	47	37	39	25	149
41	Mt. Lewotobi, Flores	1	40	49	41	27	158
35	Mt. Delaki, Pantar	1	39	46	47	27	160
30	Mt. Egon, Flores	1	42	44	39	36	162
45	Mt. Lewotobi, Flores	1	49	46	36	32	164
59	Lelogama, Timor	1	51	41	37	37	167
44	Mt. Lewotobi, Flores	1	43	51	50	26	171
67	Lelogama, Timor	1	25	52	52	42	172
36	Mt. Wulogai, Flores	2	54	47	47	26	176
51	Mt. Wasbilla, Pantar	1	50	48	42	35	176
21	Mt. Lewerok, Flores	2	44	50	51	31	178
46	Mt. Sirung, Pantar	1	45	57	47	30	180
22	Mt. Wasbilla, Pantar	1	56	42	51	33	183
34	Mt. Delaki, Pantar	2	38	57	48	38	183
68	Remexio, Timor	1	36	54	53	44	188
43	Mt. Lewotobi, Flores	2	53	51	54	31	191
4	Ampui, Alor	1	52	53	49	41	196
70	Mt. Lakaan, Timor	10	59	53	46	28	196
58	Mt. Kerbau, Lomblen	5	68	60	58	11	202
64	Lelogama, Timor	3	55	55	55	35	203
66	Lelogama, Timor	3	57	56	59	32	207
52	Mt. Wasbilla, Pantar	2	54	61	61	32	210
40	Mt. Sirung, Pantar	1	60	62	56	36	215
42	Mt. Mutis, Timor	1	66	63	60	25	215
27	Mt. Wokoh, Flores	3	65	55	57	38	218
15	Mt. Mandiri, Flores	1	58	58	63	39	219
71	Ermera, Timor	4	64	63	62	29	222
72	Ermera, Timor	9	61	64	61	27	222
63	Mt. Kerbau, Lomblen	6	67	65	64	23	225
19	Mt. Lewotobi, Flores	1	62	64	65	42	234
17	Mt. Sirung, Pantar	5	63	64	66	45	243
73	Mt. Boleng, Flores	8	69	66	67	43	253

CONCLUSIONS

Provenance variation of Timor Mountain Gum's growth and morphological characteristics at Lad Krating Plantation, Chachoengsao are concluded as follows.

Average survival percent drop gradually from ages 6, 8, 10 to 16 years, with 85%, 79%, 75% to 54% respectively. Although throughout the 16 years, provenances from Mt. Mandiri, Flores (No.5), Mt. Sirung, Pantar (No. 11) and Lelogama, Timor (No. 18) were the top surviving provenances, this trend change at 16 years when provenances from Ampui, Alor (No. 10) and Mt. Kerbau (No. 7) emerged as better surviving. Survival percentages had statistically highly significant differences between provenances at all ages.

Average tree height increased from 18m, 20m, 21m to 25m at ages 6, 8, 10 and 16 years respectively. The best performing provenance was from Mt. Lewotobi, Flores (No. 6) at 28.86m at age 16 years; while Ililaku, Wetar (No. 22) provenance was the least performing at all ages with a height of 22.12m at 16 years old. There were statistically highly significant differences of this growth trait between provenances at all ages. Correlation between height and length of clear bole was strong and highly significant (0.774, $p<0.01$).

DBH increased from 16.34cm, 17.74cm, 18.99cm to 23.57cm in sequence at 6, 8, 10 and 16 years after planting. The best performing provenances at all ages was from Mt. Lewotobi, Flores (No. 6) with a DBH of 26.84cm at 16 years old. The least performing provenance at age 16 years was from Mt. Mandiri, Flores (No. 5) with a DBH of 18.39cm. The variation of average DBH were statistically highly significant ($p<0.01$) between provenances at all ages except at age 16 years, which was only significantly different ($p<0.05$).

As with previous growth traits, average D10 increased with tree age sequentially from 19.59cm, 21.25cm, 22.57cm to 29.79cm at the age of 6, 8, 10 and 16 years. The variation of average D10 amongst provenances were statistically highly significant ($p<0.01$) at all ages. Provenance Mt. Lewotobi, Flores (No. 6) performed consistently well at all ages with a D10 of 32.48cm at 16 years old. The least performing provenance was from Mt. Lelogama, Timor (No. 18) with a D10 of 27.1cm at 16 years old. Height, DBH, and D10 rate of increments was highest during initial growth periods (the first six years).

Only 19.1% had straight stem form in the provenance trials, while the others had undesirable stem forms. Variation of stem forms between provenances were not statistically significant ($p>0.05$) but were highly significant within provenances ($p>0.01$). Stem straightness is moderately heritable, as demonstrated in *Pinus taeda* L., where inheritance was relatively high for crook, but sweep was moderately weakly inherited (Ehrenberg, 1970).

There were only 23% of rough barks (4, 9, 10, 11) compared to the rest of the smooth barks. Bark types was not significantly different amongst provenances, but was highly significant (p<0.01) in variation within the provenances. Bark thickness ranged from 0.2-1.2cm for all bark types. Rough barks (bark types 9, 10, 11 – fibrous and subfibrous) had higher mean average thickness than smooth barks.

Average leaf area was between 28.39cm^2 (Lelogama, Timor, No.18) to 52.23cm^2 (Remexio, Timor, No.15) with an average of 39.86cm^2. The stomata which were only present on the abaxial leaf surface of Timor Mountain Gum, averaged at 355.45 stomata/mm^2. The range is quite wide between 249.37 (Mt. Mandiri, Flores, No.5) to 515.25 stomata/mm2 (Mt. Egon, Flores, No.1). Variation were statistically insignificant (p>0.05) between provenances for all of the leaf characters with the exception of stomata density which had significant variation (p<0.05) between provenances.

The summation and scoring of growth characteristics for the ranking of the overall best performing provenances indicated that provenance No.6 (Mt. Lewotobi, Flores) a lowland provenance was ranked first. Meanwhile, the least performing provenance was from Mt. Boleng, Flores (No.8) a high altitude provenance. The performances of the best and least ranked provenances were consistently matched at 10 years and 16 years old. In general progenies from low altitudes in the islands of Flores were the selected best in China and Brazil (Scanavaca and Garcia, 2003) for tree improvement program. In Indonesia, early trials favored provenances Kaplung, Wetar Island (Siagian, 2004).

The study on the variation of growth characteristics in the progeny testing of Timor Mountain Gum are concluded here:

The overall mean above-ground biomass was 13.36kg, with a range of 0.47-42.11kg. Biomass partitioning was greatest in stem wood (10.18kg), followed by branch wood (2.17kg) and leaves (1kg) on average. Above-ground biomass has a strong correlation with growth characteristics – height, crown diameter, DBH and D10 (above 0.80, p<0.01). Mean harvest index, form quotients, and crown ratio were 0.73, 0.68, and 0.36 respectively.

Average survival percentage was a high 97.34%, but varied considerably between progenies from 70-100%. Height averaged at 12.09m, and ranged from 8.48m (Family 12) to 13.47m (Family 73). DBH has an average of 8.83cm and differed from 6.67cm (Family 73) to 9.76cm (Family 8). The average figure for D10 was 10.45cm, within the range of 8.06m (Family 73) to 11.67cm (Family 8), which families are similar to those of DBH. The variation in crown diameter was between 1.58m (Family 17) to 2.19m (Family 5) with an average of 1.96m. About 80% of trees in the progeny trials had straight stem. This percentage of straight stem varied a great deal amongst families, between 40% (Family 58) to 96% (Family 62). There were statistically highly significant (p<0.01) differences among provenances and blocks for all the growth characteristics of the Timor Mountain Gum progenies with

the exception of the variation of survival percentages between blocks were insignificant (p>0.05).

Correlation indicated the existence of strong and statistically highly significant relationship between total height and clear bole (0.724**), and between DBH and D10 (0.916**). Correlation between other growth characteristics were low (0.183*) to moderate (0.520**).

Narrow sense heritability was moderately high, more than 0.50 for all the growth traits with the exception of survival trait, which may be influenced by environmental factors. The narrow sense heritability for survival was 0.303 and for the growth characteristics are as follows: total height (0.613), DBH (0.774), D10 (0.740), crown diameter (0.513), and stem forms (0.518). Thus, wide range of genetic content will allow for selection to maximize wood production and enhance wood quality.

The summation and scoring of growth characteristics for the ranking of the overall best performing provenances indicated that the ten best ranking families were from Ermera, Timor (8), Mt. Lewotobi, Flores (18), Ermera, Timor (7), Ampui, Alor (3), Mt. Egon, Flores (9), Mt. Egon, Flores (77), Mt. Sirung, Pantar (12), Mt. Mutis, Timor (25), Mt. Sirung, Pantar (11) and Remexio, Timor (38). These are recommended for selection and future use in tree breeding program.

RECOMMENDATIONS

Recommendations are made here for future tree improvement and breeding programs of Timor Mountain Gum.

The provenance trials have shown progression and changes in economically important growth traits and should be maintained for re-assessment up till 30 years-old, where these are assessed for lumber or sawn wood performances. Timor Mountain Gum has proven even more useful and valuable as a hybrid material especially with *Eucalyptus grandis* in Congo, Brazil and China that are used not only for pulp production but also for sawn wood production. Therefore, screening for selected families and the best clones of Timor Mountain Gum for future hybridization and clonal tests are some of the promising options. Therefore, the study on vegetative propagation method for Timor Mountain Gum and its hybrids are equally important. Timor Mountain Gum hybrids have been grown successfully in plantations of the tropical warm climate. Therefore, hybridization work of Timor Mountain Gum with related eucalypts species is recommended. Research on flowering time and seed ontogeny among families will also yield beneficial information for the establishment of future seed orchards. At least 75% of flowering synchronization is needed to promote out-crossing pollination amongst the families. Study on full-sib and half-sib progenies arising from controlled pollination is also needed. The progeny tests require further rouging to select the best tree of each plot in the seed orchard. But, this should only be carried out after the trees has adapted to the strong wind condition of the plantation. Variations of some growth characteristic among blocks were significant, and thus, the study of species-site interaction in relation to soil fertility should be considered. There is also the need to study the effects of fertilizer application to activate seed crop production of selected Timor Mountain Gum families. Thai Plywood Co. Ltd.'s main products are hardboards, fiber boards, and the medium-density fiber board which utilizes mainly eucalypts pulp. Essentially, the improvement of Timor Mountain Gum should lead to enhanced wood pulp properties and maximize volume production. Therefore, future research should consider the study on the chemical, physical and mechanical wood properties of this species for future breeding program. The usefulness of this species through product expansion and value-added process has been demonstrated elsewhere. For example, timber of the hybrid *E. grandis* x *E. urophylla* grown up till 14 to 16 years in Brazil, are marketed as Lyptus wood in North America. The manufacturers, the Aracruz Wood Products in Bahia, Brazil have produced a variety of higher value products from this wood, main sliced veneer, veneer plywood, particleboard panels, edge banding, solid flooring in standard and striped grades both finished or unfinished, flitch veneers, stair parts, mouldings and veneer flooring. Other end uses for its timber include furniture, cabinets, and architectural millwork (Kaiser, 2005). Malan (2004) briefly discussed existing knowledge with regard to wood properties and qualities of *E.* grandis, and the methods employed to improve the quality of wood for lumber production. Thai Plywood Company Ltd. could expand to the production of high value end-products which are generally in demand in the local and export market with new improved

results from wood processing technologies and management systems. It is also important not to neglect the recent achievements in the field of genetic study. Molecular markers are important tools that can be applied to find out about the genetic diversity and gene flow among the population of Timor Mountain Gum provenances or progenies. The same tools can be used to infer or prove the nature of true hybrids in an open-pollinated population, which should be supported with the study on the species selfing and out-crossing capabilities. For example, Campinhos *et al.* (1998) used allozyme markers to estimate the amount of natural hybridization between *E. grandis* and *E. urophylla* in a commercial hybrid seed orchard planted in Espírito Santo, Brazil to infer contaminant pollination from progenies genotypes containing alleles not present in the parental clones. The use of molecular markers to study the genetic systems of Timor Mountain Gum had been conducted in Brazil. For instance, Gaiotto *et al.* (1997) estimated the rate of out-crossing in a breeding Timor Mountain Gum population using RAPD and RFLP markers, while Pigato and Lopes (2001) used RAPD markers to evaluate the genetic variation in Timor Mountain Gum progenies. These tools used along side silvicultural and botanical information can provide invaluable assistance to tree improvement programs.

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APPENDICES

Appendix 1 Bark types of Timor Mountain Gum at Lad Krating Plantation, Chachoengsao province

Smooth pale

Smooth mottled

Smooth trunk rough base

Fissured (Ironbark)

Tesselated

Shed in ribbons

Shed in curls

Shed in strips
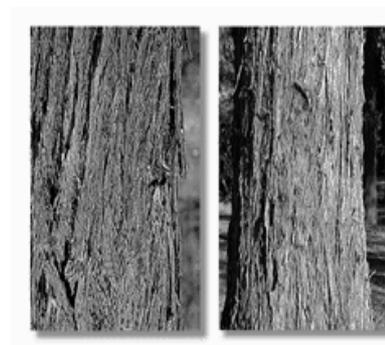
Fibrous bark

1. Smooth barks

As the outermost layer of the bark dies, it is completely shed to expose a new layer of living bark every year. These are known as smooth barks. The dead bark may be shed from the trunk of the tree in large slabs, in ribbons, or in small flakes. The newly exposed living bark is relatively smooth and brightly colored but this fades with weathering. Often the dead bark comes off in pieces at various times of the year that the trunk is mottled depending on the amount of time the newly revealed patches of bark are exposed to weathering.

Appendix 1   (continued)

Imperfectly shed curls, ribbons and strips

The bark on the stems and possibly the larger limbs appears loosely rough due to the imperfect shedding of dead bark. The general appearance is quite variable depending on whether a give species normally sheds in long coarse ribbons, shorter thin strips or in irregular flakes. This bark character should be differentiated from the loose basal slab which implies a thicker accumulation of dead bark on the lower stem or bole.

2. Rough barks

In the rough barks, the outer annual increment of dead bark simply dries out leaving the natural fibers which do not shed and which accumulate yearly. There are so many different types of rough bark, defined by their texture, color and persistence on the trunk.

Ironbarks

As in the traditional ironbarks, these species have bark that becomes hard, compacted and furrowed with age, varies in color from grey to black or red-black. Some ironbark species, however, have all the appearance of the hard furrowed ironbark character, yet is actually soft, flaky and friable.

Tesselated

The outer dead bark breaks up into small flakes (tesserae or tessellations). This bark may be loose or firmly held to the whole trunk and branches.

Fibrous and sub-fibrous bark

The bark can be recognized by the thick, longitudinally-furrowed, fibrous bark over the whole trunk such that the bark can be pulled away in long strings. The stringy barks have inner layers of stringy or fibrous bark that are crossed, with reddish under bark. The peppermint barks are rough over the trunk and often the branches, but thinner and not coarse. The fibrous boxed group often has tightly held and sometimes flaky bark. Thickness is variable and shedding is irregular or in many species does not occur at all.

Smooth trunk rough base (loose basal slab)

Some of the dead bark is held loosely over the bole for some time before it is shed, and distinguished from distinct, firmly-held rough bark.

Appendix 1 (continued)

Compacted

The bark is rough for the basal 1-3m only. This originally fibrous bark becomes suffused with exudates and hardens the barks. The bark color is invariably very dark brown to black. This type of bark may cover the whole trunk and be quite fissured, furrowed, while the branches are conspicuously smooth.

Appendix 2   Morphology of Timor Mountain Gum Leaves

Mt. Egon, Flores

Mt. Wulogai, Flores

Mt. Wokoh

Mt. Lewerok, Flores

Mt. Mandiri, Flores

Mt. Lewotobi, Flores

Mt. Kerbau, Lomblen

Mt. Boleng, Flores

Kalabahi, Alor

Ampui, Alor

Mt. Sirung, Pantar

Mt. Mutis, Timor

Appendix 2 (continued)

Mt. Delaki, Pantar

Mt. Wasbilla, Pantar

Remexio, Timor

Lelogama, Timor

Ermera, Timor

Ililaku, Wetar

Mt. Lakaan, Timor

Appendix 3 Mean value (X), phenotypic value (P), genotypic value (G) of growth characteristics, total height (m), diameter 10cm above ground (D10, cm), diameter at breast height (DBH, cm), crown diameter (m), and stem forms of Timor Mountain Gum progenies at Lad Krating Plantation, Chachoengsao

Famili	Total height			D10			DBH			Crown diameter			Stem forms		
	X (m)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (m)	P (%)	G (%)	X (n)	P (%)	G (%)
1	12.11	-87.89	-53.88	10.34	-89.66	-66.35	8.70	-89.68	-69.41	2.11	-97.89	-50.22	1.74	-98.26	-50.90
2	12.69	-87.31	-53.52	11.04	-88.96	-65.83	9.36	-97.19	-75.22	2.09	-97.91	-50.23	1.38	-98.63	-51.09
3	12.89	-87.11	-53.40	11.23	-88.77	-65.69	9.59	-99.78	-77.23	2.08	-97.92	-50.23	1.38	-98.63	-51.09
4	11.68	-88.32	-54.14	9.91	-90.09	-66.67	8.39	-86.14	-66.67	1.69	-98.31	-50.43	1.76	-98.24	-50.89
5	12.69	-87.31	-53.52	11.00	-89.00	-65.86	9.45	-98.18	-75.99	2.20	-97.80	-50.17	2.50	-97.50	-50.51
6	12.23	-87.77	-53.80	10.88	-89.12	-65.95	9.27	-96.13	-74.41	2.11	-97.89	-50.22	1.52	-98.48	-51.01
7	13.23	-86.77	-53.19	11.19	-88.81	-65.72	9.43	-97.94	-75.81	2.08	-97.92	-50.23	1.67	-98.33	-50.93
8	12.75	-87.25	-53.49	11.65	-88.35	-65.38	9.75	-101.62	-78.66	2.19	-97.81	-50.18	1.53	-98.47	-51.01
9	12.82	-87.18	-53.44	11.53	-88.47	-65.47	9.62	-100.09	-77.47	2.19	-97.81	-50.18	1.40	-98.60	-51.08
10	12.67	-87.33	-53.53	10.94	-89.06	-65.90	9.28	-96.26	-74.50	1.99	-98.01	-50.28	1.42	-98.58	-51.07
11	12.52	-87.48	-53.62	11.03	-88.97	-65.84	9.63	-100.20	-77.55	2.16	-97.84	-50.19	1.81	-98.19	-50.86
12	13.47	-86.53	-53.04	11.26	-88.74	-65.67	9.53	-99.09	-76.69	1.95	-98.05	-50.30	1.55	-98.45	-51.00
13	12.74	-87.26	-53.49	10.98	-89.02	-65.87	9.31	-96.63	-74.79	1.92	-98.08	-50.31	1.91	-98.09	-50.81
14	11.84	-88.16	-54.04	11.02	-88.98	-65.85	9.42	-97.83	-75.72	2.28	-97.72	-50.13	1.53	-98.47	-51.01
15	11.30	-88.70	-54.37	9.82	-90.18	-66.74	8.03	-82.09	-63.54	1.74	-98.26	-50.41	1.50	-98.50	-51.02
16	12.33	-87.68	-53.74	10.69	-89.31	-66.09	9.15	-94.77	-73.35	2.09	-97.91	-50.23	1.60	-98.40	-50.97
17	11.05	-88.95	-54.52	9.31	-90.69	-67.11	7.74	-78.78	-60.98	1.59	-98.41	-50.49	1.34	-98.66	-51.11
18	12.74	-87.26	-53.49	11.46	-88.54	-65.52	9.68	-100.78	-78.00	2.14	-97.86	-50.20	1.28	-98.72	-51.14
19	11.10	-88.90	-54.50	9.57	-90.43	-66.92	7.86	-80.18	-62.06	1.70	-98.30	-50.43	1.50	-98.50	-51.02
20	12.02	-87.98	-53.93	11.00	-89.00	-65.86	9.11	-94.38	-73.05	2.15	-97.85	-50.20	1.50	-98.50	-51.02
21	11.86	-88.14	-54.03	10.05	-89.95	-66.57	8.46	-86.94	-67.29	1.87	-98.13	-50.34	1.87	-98.13	-50.83
22	11.51	-88.49	-54.24	10.23	-89.77	-66.43	8.44	-86.78	-67.17	1.83	-98.17	-50.36	1.69	-98.31	-50.93
23	11.85	-88.15	-54.03	10.44	-89.56	-66.28	8.80	-90.85	-70.31	1.99	-98.01	-50.28	1.89	-98.11	-50.82
24	12.66	-87.34	-53.54	11.03	-88.97	-65.84	9.14	-94.69	-73.29	2.15	-97.85	-50.19	1.38	-98.62	-51.09
25	12.65	-87.35	-53.55	11.04	-88.96	-65.83	9.22	-95.63	-74.01	2.04	-97.96	-50.25	1.94	-98.06	-50.79

Appendix 3   (continued)

Famili	Total height			D10			DBH			Crown diameter			Stem forms		
	X (m)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (m)	P (%)	G (%)	X (n)	P (%)	G (%)
26	12.44	-87.56	-53.68	10.74	-89.26	-66.05	9.15	-94.81	-73.38	2.08	-97.92	-50.24	1.36	-98.64	-51.10
27	11.02	-88.98	-54.55	9.92	-90.08	-66.66	8.16	-83.63	-64.73	1.76	-98.24	-50.40	2.11	-97.89	-50.71
28	12.06	-87.94	-53.91	10.87	-89.13	-65.96	9.10	-94.20	-72.91	2.07	-97.93	-50.24	2.93	-97.07	-50.28
29	11.97	-88.03	-53.96	10.61	-89.39	-66.15	8.95	-92.53	-71.62	2.11	-97.89	-50.22	1.75	-98.25	-50.89
30	11.93	-88.07	-53.99	10.20	-89.80	-66.46	8.73	-89.99	-69.65	1.80	-98.20	-50.38	1.15	-98.85	-51.21
31	12.46	-87.54	-53.66	10.32	-89.68	-66.37	8.88	-91.70	-70.97	1.95	-98.05	-50.30	1.24	-98.76	-51.16
32	12.07	-87.93	-53.90	10.51	-89.49	-66.22	8.85	-91.44	-70.78	1.99	-98.01	-50.28	1.51	-98.49	-51.02
33	11.87	-88.13	-54.02	10.51	-89.49	-66.22	8.76	-90.40	-69.97	1.96	-98.04	-50.30	1.27	-98.73	-51.14
34	11.98	-88.02	-53.96	9.82	-90.18	-66.73	8.46	-87.01	-67.35	1.77	-98.23	-50.39	1.43	-98.57	-51.06
35	11.97	-88.03	-53.96	10.14	-89.86	-66.50	8.51	-87.57	-67.78	1.94	-98.06	-50.31	1.71	-98.29	-50.91
36	11.59	-88.41	-54.19	10.09	-89.91	-66.53	8.49	-87.31	-67.58	1.94	-98.06	-50.30	1.40	-98.60	-51.07
37	12.01	-87.99	-53.94	10.98	-89.02	-65.88	9.33	-96.81	-74.93	2.35	-97.65	-50.09	1.85	-98.15	-50.84
38	12.71	-87.29	-53.51	11.15	-88.85	-65.75	9.36	-97.18	-75.21	2.06	-97.94	-50.24	1.26	-98.74	-51.15
39	12.14	-87.86	-53.86	10.91	-89.09	-65.93	9.27	-96.12	-74.39	2.21	-97.79	-50.17	1.44	-98.56	-51.06
40	11.26	-88.74	-54.40	9.65	-90.35	-66.86	8.20	-84.02	-65.03	1.79	-98.21	-50.38	1.15	-98.85	-51.21
41	11.98	-88.02	-53.96	10.07	-89.93	-66.55	8.61	-88.68	-68.64	1.92	-98.08	-50.31	1.19	-98.81	-51.18
42	10.71	-89.29	-54.73	9.41	-90.59	-67.04	8.15	-83.45	-64.59	1.96	-98.04	-50.30	1.76	-98.24	-50.89
43	11.52	-88.48	-54.24	9.96	-90.04	-66.63	8.31	-85.29	-66.01	1.85	-98.15	-50.35	1.53	-98.47	-51.01
44	11.95	-88.05	-53.98	10.01	-89.99	-66.59	8.44	-86.77	-67.16	1.93	-98.07	-50.31	1.78	-98.22	-50.88
45	11.75	-88.25	-54.10	10.12	-89.88	-66.51	8.79	-90.71	-70.21	1.84	-98.16	-50.35	1.67	-98.33	-50.94
46	11.85	-88.15	-54.03	9.84	-90.16	-66.72	8.50	-87.39	-67.64	1.87	-98.13	-50.34	2.08	-97.92	-50.72
47	12.67	-87.33	-53.53	10.75	-89.25	-66.05	9.16	-94.92	-73.47	2.14	-97.86	-50.20	1.69	-98.31	-50.93
48	12.99	-87.01	-53.34	10.05	-89.95	-66.57	8.67	-89.36	-69.16	1.94	-98.06	-50.31	1.89	-98.11	-50.82
49	12.92	-87.08	-53.38	10.22	-89.78	-66.44	8.74	-90.13	-69.76	2.09	-97.91	-50.23	1.44	-98.56	-51.06
50	11.47	-88.53	-54.27	10.18	-89.82	-66.47	8.57	-88.26	-68.31	1.83	-98.17	-50.36	2.17	-97.83	-50.68
51	11.70	-88.30	-54.13	10.08	-89.92	-66.54	8.60	-88.57	-68.55	1.81	-98.19	-50.37	1.77	-98.23	-50.88
52	11.54	-88.46	-54.22	9.65	-90.35	-66.86	8.08	-82.63	-63.95	1.86	-98.14	-50.34	1.85	-98.15	-50.84

Appendix 3   (continued)

Famili	Total height			D10			DBH			Crown diameter			Stem forms		
	X (m)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (cm)	P (%)	G (%)	X (m)	P (%)	G (%)	X (n)	P (%)	G (%)
53	11.80	-88.20	-54.07	10.64	-89.36	-66.12	8.87	-91.57	-70.87	1.90	-98.10	-50.33	1.85	-98.15	-50.84
54	12.46	-87.54	-53.66	11.03	-88.97	-65.84	9.31	-96.56	-74.74	2.24	-97.76	-50.15	1.91	-98.09	-50.81
55	12.43	-87.57	-53.68	10.78	-89.22	-66.03	9.20	-95.41	-73.85	1.98	-98.02	-50.28	1.89	-98.11	-50.82
56	12.23	-87.77	-53.80	10.65	-89.35	-66.12	9.02	-93.37	-72.27	2.08	-97.92	-50.23	1.57	-98.43	-50.98
57	12.21	-87.79	-53.81	10.38	-89.62	-66.32	8.86	-91.50	-70.82	1.83	-98.17	-50.36	1.27	-98.73	-51.14
58	10.12	-89.88	-55.10	9.70	-90.30	-66.82	8.17	-83.74	-64.82	2.17	-97.83	-50.19	2.95	-97.05	-50.27
59	11.65	-88.35	-54.16	10.24	-89.76	-66.43	8.77	-90.50	-70.05	1.78	-98.22	-50.38	1.51	-98.49	-51.02
60	12.63	-87.38	-53.56	11.13	-88.87	-65.77	9.48	-98.54	-76.27	2.03	-97.97	-50.26	1.66	-98.34	-50.94
61	12.72	-87.28	-53.50	10.24	-89.76	-66.42	8.56	-88.15	-68.23	1.72	-98.28	-50.42	1.14	-98.86	-51.21
62	12.77	-87.23	-53.47	10.93	-89.07	-65.91	9.44	-98.06	-75.90	1.96	-98.04	-50.29	1.04	-98.96	-51.26
63	10.45	-89.55	-54.89	9.34	-90.66	-67.09	7.95	-81.16	-62.82	1.97	-98.03	-50.29	2.08	-97.93	-50.73
64	11.50	-88.50	-54.25	9.85	-90.15	-66.71	8.30	-85.16	-65.91	1.80	-98.20	-50.38	1.57	-98.43	-50.99
65	12.29	-87.71	-53.77	11.08	-88.92	-65.80	9.40	-97.68	-75.60	2.02	-97.98	-50.26	1.61	-98.39	-50.97
66	11.50	-88.50	-54.25	9.99	-90.01	-66.60	8.22	-84.23	-65.20	1.83	-98.17	-50.36	1.50	-98.50	-51.02
67	12.37	-87.63	-53.72	9.95	-90.05	-66.63	8.40	-86.25	-66.76	1.69	-98.31	-50.43	1.55	-98.45	-51.00
68	12.01	-87.99	-53.94	9.97	-90.03	-66.62	8.38	-86.12	-66.65	1.64	-98.36	-50.46	1.39	-98.61	-51.08
69	12.58	-87.42	-53.59	10.87	-89.13	-65.95	9.21	-95.43	-73.86	2.34	-97.66	-50.10	1.65	-98.35	-50.95
70	11.18	-88.82	-54.44	9.97	-90.03	-66.62	8.53	-87.78	-67.94	1.90	-98.10	-50.32	1.68	-98.32	-50.93
71	11.03	-88.97	-54.54	9.62	-90.38	-66.88	8.10	-82.94	-64.19	1.89	-98.11	-50.33	1.40	-98.60	-51.07
72	11.04	-88.96	-54.53	9.37	-90.63	-67.06	8.15	-83.47	-64.60	1.96	-98.04	-50.30	2.46	-97.54	-50.53
73	7.85	-92.15	-56.49	7.55	-92.45	-68.42	6.16	-60.98	-47.20	1.55	-98.45	-50.50	1.73	-98.27	-50.90
74	12.90	-87.10	-53.39	10.73	-89.27	-66.06	8.95	-92.49	-71.59	1.88	-98.12	-50.34	1.35	-98.65	-51.10
75	13.07	-86.93	-53.29	11.03	-88.97	-65.84	9.22	-95.54	-73.95	2.05	-97.95	-50.25	1.84	-98.16	-50.85
76	12.79	-87.21	-53.46	10.95	-89.05	-65.90	9.42	-97.85	-75.74	1.96	-98.05	-50.30	1.29	-98.71	-51.13
77	12.85	-87.15	-53.42	11.34	-88.66	-65.61	9.72	-101.27	-78.39	2.03	-97.97	-50.26	1.66	-98.34	-50.94
78	12.11	-87.89	-53.88	10.73	-89.27	-66.06	9.14	-94.64	-73.25	2.04	-97.96	-50.26	1.70	-98.30	-50.92
79	12.91	-87.10	-53.39	10.71	-89.29	-66.07	9.16	-94.85	-73.41	2.10	-97.90	-50.22	1.45	-98.55	-51.05
80	12.50	-87.50	-53.64	10.84	-89.16	-65.98	9.01	-93.16	-72.10	2.13	-97.87	-50.21	1.30	-98.70	-51.12

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