Kenya Forestry Research Institute

Performance Of Australian, Central American And Kenyan Tree Species In Arid Sites Of Embu, Meru And Isiolo Districts

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Summary

This report covers an evaluation of forestry trials that were established by EMI project between 1984 and 1990. The trials' objective was to select appropriate tree species and provenances for planting in the Arid and Semi-Arid Lands. This was based on felt needs caused by the ever increasing demand of forestry products at a time when clearing of natural vegetation for crop production was rampant. Therefore, anticipated products of tested species included poles and a variety of other farm forestry products.

Growth and survival were the assessment parameters included in the initial designs. The present evaluation has restricted itself to these parameters.

Results of the current assessment revealed that height was the best factor of differentiating species and provenances on growth. Survival was distorted by tree cutting. However, survival ranged from 100% to 0% for the species tested in the trials that were evaluated, suggesting varied adaptability of species and provenances. *Eucalyptus camaldulensis*, *E. melanophloia* and *E. microtheca* are some of the species that were identified as appropriate for production of poles. *Acacia salicina, Melia volkensii* and *Senna atomaria* were the other species with good agroforestry potential.

It is recommended that survival of 40% be adopted as borderline for adaptability. From this criterion, species with a survival of less than 40% should be cleared. This will avail more growing space to more adaptive species. The adaptive species should be thinned to a minimum spacing of 3m by 3m to reduce competition, while multi stemmed species should be thinned to a single stem.

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CHAPTER 1: INTRODUCTION

1.0: Background

This report covers an assessment of Forestry trials established in Embu, Meru and Isiolo Districts by the former Embu, Meru and Isiolo (EMI) project. The trials are within the Arid and Semi-Arid Lands (ASALs). These trials were established between 1983 and 1990 at Gangara, Gategi, Kadeveni, Kathwana, Lanciathurio, Marimanti, Muramba, Nkado and Thiba. The last assessment was done in 1986. Since tree growth is a long term process, this assessment is justified to provide technical support for forestry projects working in other ASALs of Kenya. The approximate location of these sites within Embu, Meru and Isiolo Districts is shown in Figure 1.

According to Sombroek et al. (1982) ASALs are classified as those areas within agroclimatic zones IV-VII. They are characterized by low rainfall and high evaporation potential such that the rainfall evaporation ratio (r/E_o) ranges from 0.5-<0.15. A low r/E_o indicates that potential evaporation loss of water is greater than rainfall. Areas with such low ratios are exposed to meteorological drought (Levitt 1980) which induces water stress in plants (Kramer 1986). The need to identify plants that can tolerate or avoid water stress for planting in such areas cannot be overemphasized. The forestry trials of EMI project was a fulfilling contribution towards this end. Areas with comparable site conditions are expected to benefit from results of such work.

1.1: Objectives

The objective of this assessment was to describe the trials in terms survival, height and diameter for the tested species. These parameters are used to evaluate adaptability of species and its potential to provide desired products. Statistical analysis and volume determination was also undertaken where appropriate.

Important characteristics of trial sites as adopted from trial establishment reports are described because site conditions can be used to extrapolate findings to areas with comparable attributes. The site factors described are geographical position, soils, slope, altitude, natural vegetation, previous land use, site preparation and maintenance of forestry trials. This description is provided for Gategi, Kathwana, Lanciathurio, Muramba and Nkando because thorough assessment was done in those areas.

1.2: Approach

Height and diameter were measured as described later. The present tree stock was recorded for survival determination. In Gategi, Kathwana, Lanciathurio, Muramba and Nkando statistical data analysis was undertaken. In Gangara, Kadeveni and Marimanti the data was scanty and mean height and diameter of surviving trees was determined and attached in appendix I. At Thiba, it was not possible to identify *Eucalyptus camaldulensis* provenances that were tested. Therefore data from this site was omitted in the analysis.

CHAPTER 2: MATERIAL AND METHODS

2.0 Introduction

This chapter covers site description, site preparation, experiment establishment and maintenance and methods of data collection and analysis.

2.1.0: Site Description

The characteristics of trial sites is summarized in Table 1 while soils and vegetation types are described below.

2.1.1: Legend for soils description

Gategi was the only site where soil analysis was done before establishment of the forestry trial. Results of this analysis is described below, as adopted from Armstrong and Lugadiru (1986). In other sites, soil description is based on the general report of Sombroek et al. (1982).

(a) Chromic Vertisols (Gategi)

These are imperfectly drained black cotton soils with a p^H range of 7.6-7.9 and have defined A, B, and C soil horizons. Before trial establishment, the soils were assessed. At that time, avail able nutrients in mg/100g of soil was 1.02, 0.16 and 23.00 for sodium, potassium and calcium respectively, while phosphorous level was 10ppm. They have a clay texture.

(b) Chromic Luvisols (Kathwana)

Chromic luvisols are well drained dark brown clay loams. These soils have a rooting depth of 80-18-cm. Although soils from this site were not analyzed, the fertility was rated low because the area was heavily degraded. Soil erosion was a common feature due to soil compaction and soil capping at the onset of rains. The p^H of such soils is in the range of 6.0-7.0.

(c) Humic Nitisols (Lanciathurio and Muramba)

Humic nitisols are well drained clay soils with a rooting depth of >150cm. The soils were not analyzed but their water holding capacity is known to be high. These soils are calcareous, a soil condition which limit the uptake of Boron and Molybdenum, with subsequent reduction in productivity of plants that are sensitive to micronutrients. The p^H ranges between 7.0-7.5, while the colour is dark reddish brown to dark red.

(d) Verto-Luvic Phaeozems (Nkando)

Verto-luvic phaeozems are shallow clay soils with an effective rooting depth of 70cm. These soils are intercepted by unweathered volcanic ashes and their p^H is likely to be in the range of 7.0-8.0. They are dark greyish brown in colour.

2.1.2: Legend for Natural Vegetation

The natural vegetation of trial sites had been disturbed through human activity. The description provided represents what was expected in the absence of human interference.

(a) Bushed grassland (Gategi)
Before the establishment of the forestry trial, the site had been under maize and sorghum production. The natural vegetation of this area consists of bushed grassland dominated by shrubs and herbs such as *Abutilon mauritianum, Acacia drepanolobium* and *Sonchus scheinfurtii*. *Balanites aegyptica* is the most common tree while dominant grasses are *Digitaria scalarum, Sorghum sudaneusis* and *Latipes senegalensis*.

By the time of trial establishment, most of the natural vegetation had been cleared and tree population devastated. This justified initiation of forestry trial to provide alternative tree species that could be adaptable to the area. The objective of the trial was to screen species for adaptability in terms survival and growth.

(b) Acacia/Commiphora (Kathwana)
Prior to establishment of forestry trials, the site was fallow after been used for crop production under shifting cultivation. The area was therefore devoid of any natural vegetation. Nevertheless, natural vegetation of this area is *Acacia/Commiphora* association, dominated by a variety of *Acacia* species. Other species found in the area are *Delonix elata, Dichrostachys cineria* and *Terminalia* species. The understorey is dominated by perennial shrubs and grasses.

(c) Acacia/Commiphora (Lanciathurio)
Prior to plot establishment, the site had not been exposed to agriculture but had just been cleared of its natural vegetation. The vegetation of the area consists of *Acacia /Commiphora* bush land. Indigenous tree species include *Acacia tortilis, A. nilotica, A. senegal* and *Commiphora* species. The ground is covered by perennial herbs and shrubs with *Digitaria scalarum* being the most common grass.

(d) Savannah (Muramba)
The natural vegetation of this area is savannah. Common tree species include *Commiphora* species, *A. nilotica, A. seyal, A. tortilis* and *B. aegyptica*.

(e) Wooded grassland (Nkando)
The natural vegetation consists of perennial grasses with medium to dense bush and tree cover dominated by *A. seyal, A. drepanolobium, A. nilotica, A. tortilis, B. aegyptiaca, Croton dichogamous* and *Grewia* species.

2.2: Site preparation and maintenance
The methods of site preparation and maintenance of experimental plots in each site is summarized in Table 2. Protection of trials was achieved by fencing and supplemented with a guard. The plots are well maintained up to now, although the guards have long been laid off. This suggests community's good will in the management of those trials.

2.3: Trial objectives and experimental design

The broad objective of all the trials was to evaluate adaptability of tested species on site. The anticipated end use of those species was broad. Specific uses included provision of poles, posts and a variety of farm forestry products. At Gategi, effects of land preparation method on tree growth and survival was also tested. The summary of these trials is shown in Table 3, while list of species and plot layouts are attached in appendix II. Site maps are attached for Kathwana, Lanciathurio and Nkando because there were several experiments in those areas.

2.4: Data collection and analysis

In all trials height and diameter at breast height (DBH) were assessed while survival and volume assessment were undertaken in some experiments as highlighted in the site reports. The following data collection methods were adopted for all sites.

2.4.1: Height Assessment

Height (m) was measured with a measuring rod for trees with a height of up to 5m while the height of taller trees was determined with a Suunto. Although trees at Muramba were tall, the stand was dense to an extent that the use of a Suunto was impossible. Height for this site was therefore determined from the length of trees that were thinned to reduce stand density by 50%. This was justified by observed crowding of tree which had led to weak stems.

2.4.2: Diameter Measurement

Diameter at breast height was measured with a diameter tape. For trees with multiple stems, a DBH of the best stem was measured. The approach was adopted because it was found that most multi stemmed trees were dominated by a single good stem and several other weaklings that required thinning in subsequent management interventions. Indeed, thinning of multi stemmed trees to a single stem was also an objective of plot management. Therefore, selection of the best stem was considered necessary to provide a basis of unbiased growth comparison of such species with others species that were tested on the same site.

The tape was also used to determine diameters at 1m intervals for trees that were felled for volume determination. The trees were felled at stump height, taken at approximately 30cm from ground level. Felled stem diameters were measured up to a maximum possible length. In most cases diameters were measured to a top diameter of 3.0cm.

2.4.3: Survival

While collecting data on height and diameter, missing trees were recorded with details indicating whether the loss arose from natural mortality or cutting. Tree loss through felling or mortality was particularly important in Gategi site. Such differentiation could be used to determine species adaptability or its preference by local community as gauged from the number of stems cut. The mortality of the different tree species was then determined from the difference between the number of seedlings planted at the beginning of the experiment and the number found during the present assessment.

2.4.4: Volume calculations

Diameters of felled trees was entered in Lotus and volume of 1m logs determined using Smalians formula. According to this formula, the volume of a log is equal to $(a+b)/2 * l$ where a and b are the cross section areas of the posterior and anterior ends of a log of a length l. In this assessment the units were in cm and therefore the logs used in volume determination were of uniform length of 100cm.

With the exception of diameter at stump height and top diameter all other diameters were used in determining the volume of two logs because they were shared by two consecutive logs. The total tree volume in cm^3 was therefore the sum of all the possible logs in a tree. This volume was converted into cubic metres (m^3) per tree and used in further analysis to determine variations among species or provenance. The results were given in terms of mean tree volume.

2.4.5: Determination of volume equations

Volume was determined for *E. camaldulensis* and *E. microtheca* provenances. There were 30, and four provenances of *E. camaldulensis* at Muramba and Gategi respectively. Five provenances of *E. microtheca* from Gategi were also included in volume assessment.

Calculated volumes were correlated with height and diameter using Spearman's Correlations. To generate volume equations, calculated volumes were regressed against height and/or diameter using several regression models. Regression equations were used to predict tree volumes based on data collected in the field. Predicted volumes were compared with actual (calculated) volumes and equations that lead to highest correlation between the two volumes adopted for specific sites.

2.4.6: Statistical Analysis

Data from each site was sorted out to decide whether statistical analysis was feasible depending on original design and the number of trees found in experimental units (plots) of each trial. Plots with a minimum of 3 trees were included in analysis of variance mostly to determine species or provenance variation, since block effects was frequently interfered with by natural mortality and cut trees.

Analysis of variance (ANOVA) was tested using the General Linear Model Procedure (Proc GLM) of SAS and means separated by Duncan multiple range test. Variable means and corresponding standard errors were determined with Mean Procedure (Proc mean) of SAS and illustrations to highlight variable differences drawn with Cricket Graphics. Results of these assessments are reported on site basis. Data from Gangara, Kadeveni and Marimanti could not be analyzed because of mortality or cutting. At Thiba, identification of *Eucalyptus camaldulensis* provenances was not possible and no analysis was done.

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter describes the results of data assessment and analysis of trials at Gategi, Kathwana, Lanciathurio, Muramba and Nkando. Each site is discussed separately because it was not possible to compare sites due to weaknesses noted in the initial trial designs. However, result on volume equations is combined for Gategi because the method of their determination was similar.

4.1: Gategi trial

4.1.1: Summary of trial plot

The trial was laid out in 6 blocks using plots of 16 trees per plot. Blocks I, II and III were established on a tractor ploughed site while blocks IV, V and VI were established on a site that was deep-ripped with a bulldozer. The objectives were to test adaptability of 57 species / provenances and determine if land preparation method could affect survival and growth. There were no guard rows or any clear boundaries between plots. Block VI was excluded from this assessment because there were only few trees left. A detailed evaluation of species survival on block basis at Gategi is shown in appendix III.

4.1.2: Analysis of variance on height, diameter and volume

From appendix III, it is evident that block effects on height and diameter growth could not be tested because of uneven replication of species and provenances that resulted from missing trees (dead or cut). This factor prevented the use of 4 inner trees for growth assessment of each plot. The following approach was therefore adopted to facilitate indicative statistical inferences on the data.

(a) *Eucalyptus tereticornis* and *Leucaena luecocephalla* (K8) were selected to test block effects on height and diameter growth. The choice was justified by the high survival of the two species in blocks I, III, IV and V.

(b) The above two species were divided into two sets each to provide a sample of the entire population and a sample of the 4 inner trees. The two data sets were labelled separately and means compared with Duncan multiple range test to determine whether the two data sets were distinct. This test was extended to 9 other species which had revealed greater survival but not in a consistent pattern to facilitate their inclusion in the above assessment.

(c) All species and provenances with a minimum of 3 survivors were included in analysis of variance to test the main effects of species/ provenances on height and diameter growth.

4.1.3: Height

Block effect was insignificant. This contradicted earlier findings by Armstrong and Lugadiru (1986) where height in deep-ripped blocks was higher than in tractor ploughed blocks. This suggests that the beneficial effects of deep-ripping were short lived. It may, therefore, be unnecessary to invest heavily on deep-ripping in such sites.

Border effect was also insignificant (Figure 2). This is probably because the experiment was a continuous plot and had no definite boundaries between plots. Any tree can, therefore, be measured to provide representative height of the species tested in each plot.

Species and provenances were categorized into 21 groups according to Duncan multiple range test. However, differences between groups were small and gradual. The height ranged from 17.17m in *E. maculata* to 2.12m in *A. senegal*.

To facilitate practical interpretation of the data, an arbitrary grouping was adopted to categorize the species/ provenances into 4 height classes as summarized in appendix IV. The summary was based on statistical results.

Apparently, eucalyptus performed better than other species with great variation occurring among the provenances. For example *E. microtheca* provenances were in height classes 5-10m and 10-15m while those of *E. camaldulensis* were found in height classes 10-15m and in the class that exceeded 15m.

To evaluate provenance performance, deviation of specific provenances of *E. camaldulensis* and *E. microtheca* was determined and results shown in Figures 3a and b, to reflect anticipated gain or loss depending on the provenance. Height was statistically significant for all the provenances of *E. microtheca* as revealed by mean separation using the Duncan Multiple range test. For *E. camaldulensis*, the provenances designated by batch numbers 12352 and 12346 were insignificant in height growth (Figure 2). The respective provenance described by the batch numbers used in these figures are found in appendix III.

4.1.4: Diameter

Diameter growth was also significant (P>0.05) but did not reveal great variation among species and provenances since there were only three categories revealed by the Duncan Multiple range test. However, Eucalyptus species and provenances had outperformed other species on this parameter which was consistent to that observed in height growth.

Height was found to be a better criteria of assessing growth performance because it revealed greater variations than diameter. The choice of species based on height must consider the sample size shown in the results of analysis. However, species and provenances with more than 10 replicates within the height category of 10-15m and above have great potential for this site. This is particularly so if lots of trees were cut from those species or provenances, which reveals preference of those trees by the local community.

4.1.5: Tree volume

Volume variation was highly significant (P>0.0001) among species and provenances. Mean tree volume of selected species is shown in Figure 4. As with height, volume differences were small and gradual. However, greater variations occurred within plots as evident from the error bars, probably because the sample size was small.

4.1.6: Survival assessment

Tree survival and associated loss factor is shown in appendix III. *Eucalyptus camaldulensis* was the most preferred species as evident from the higher percentage of trees that were recently cut from some provenances. This is possibly because of the fast height growth (Table 4, appendix IV) and the good tree form observed in the field. *Leuceana leucocephala* was the least preferred species since no tree had been cut in provenance K8, while only 1 tree had been cut in Ena provenance.

Species adaptability to such sites can be obtained from the survival rate. Unadaptable species are those with highest mortality while adaptable ones have lower mortality. For example, *Grevillea robusta* with a death rating of 87.5% is less adaptable compared to *L. leucocephala* (Ena) that revealed a mortality of 0%.

4.2: KATHWANA TRIALS

4.2.1: Summary of plots

In Kathwana, four trials were assessed. These were:
(i) *Melia volkensii* provenance trial,
(ii) *M. volkesii* establishment trial
(iii) Exotic species trial, and
(iv) Indigenous species trial.

All the plots were established in November 1989. Results on these trials is reported on trial basis as described above. The field layout these trials is shown in appendix iig.

4.2.2: *Melia volkensii* provenance trials

In these trials, provenance, block and interaction effects were insignificant on both height and diameter growth. Mean heights and diameters of provenances are shown in Figures 5a and b. The provenances in Figure 5a came from Kalulini (Kal) Voi, Mbololo (Mbo) and Gangara (Gan). Provenances in Figure 5b came from Gangara (A) and Kaunguni (B and C). Gangara provenance was propagated through seedlings while Kaunguni provenance was raised from seedlings (B) and cuttings (C).

Mean separation was also insignificant ($P > 0.05$), suggesting uniformity among the provenances. The survival in these two trials was over 95% and human interference minimal. It is suggested that the plots be maintained for monitoring of growth, pruning and thinning.

4.2.3: Exotic species trial

At the time of assessment , there were only five species remaining (Table 5). Since the data from Table 5 was uneven in terms of species replication, detailed statistical analysis was omitted. Means and the standard error were calculated and plotted in Figure 6 to facilitate quick comparison of species height and diameter. *Azadirachta indica* had the lowest height and diameter while *Gliricidia sepium* was the best species.

4.2.4: Indigenous species trial
The species included in this trial are shown in Table 6. Mean height and diameter were determined and results plotted in Figure 7. *Cordia sinensis* had the best growth while *Tamarindus indica* had the least. The other 2 species were intermediate.

4.3: LANCIATHURIO TRIALS
4.3.1: Summary of trials
The four research trials assessed from this site were:
(I) Australian species trial established in November 1990,
(ii) Australian Species trial established in November 1989,
(iii) Mixed species trials established in April 1989 and
(iv) Mixed species trial established in November 1988.

4.3.2: Results
Species was the only factor analyzed for variance. This factor is highly significant (P>0.0001) in all trials for both height and diameter. Mean height, diameter and survival of each trial is shown in Tables 7, 8, 9 and 10. In all tables the data was sorted in ascending order of mean height. Results of these trials suggests great potential for all the eucalyptus species. *Acacia salicina* and *A. auriculiformis* were the most promising Acacias while *A. holosericea* is less adaptable because it suffered top dieback and excessive breakage of branches. The trials have also revealed that less known Central American species such as *Albizia guachapele, Pithecolobium dulce* and *Gliricidia sepium* have a potential in the dry areas of Kenya.

On the basis of these trials, species with a survival of 40% and above can be recommended for this site, provided reasonable growth is attained. This recommendation has considered the close spacing used in those trials. Close spacing can reduce growth rates and accelerate mortality because of ensuing intraspecific and interspefic competition.

4.4: MURAMBA PROVENANCE TRIAL
4.4.1 Plot summary
The seed batch numbers of provenances tested that were at this site are shown in appendix V. These numbers have been adopted as provenances because they can easily be traced from the seed suppliers. Most provenances were replicated 18 times using 2 trees per block or 4 seedlings per block in provenances with excess seedlings. Provenance 1, 17, 19 and 25 had 17 replicates. A single guard row of excess seedlings was used without identification of provenances. A spacing of 3m by 3m was used.

Although one of the objectives was to use the plot as a seed stand, the prevailing design cannot accommodate such objective because the provenances are mixed within the plot and this can lead to cross breeding.

4.4.2: Results

Analysis of variance revealed insignificant effects of provenance, block and interaction on DBH of all the 30 provenances. This suggests that DBH is not a good criteria for segregating provenances in terms of their growth. Block and interaction effects could not be tested on height because of inconsistent replication of sampled trees among blocks. Uneven replication arose from the discarding of defective trees and those with broken tops. However, the provenances were highly significant ($P > 0.0001$) on height growth. Figure 8 shows the difference between the shortest, intermediate and the tallest provenances.

Height was considered to be a suitable criteria for comparing performance of provenances. This was achieved by assessing percentage deviation of a specific provenance from the mean height of all the 30 provenances (Figure 9). Based on Figure 9, the provenances coded as 13 and 19 were the most promising provenances while provenances coded as 1 and 18 had lowest potential. Details of provenance codes for interpretation of Figure 9 are shown in appendix V. The batch numbers shown in appendix V can be used to obtain appropriate provenances from the Australian seed source, for establishment of forest or seed stands.

4.5: NKANDO TRIALS

4.5.1: Summary of trials

The three plots assessed in this site were:

(I) ACIAR Project research trial of April 1989
(ii) Central America species trial of April 1989 and
(iii) Central America species trial of November 1988.

The results on these trials are described below.

4.5.2: ACIAR

The trial tested 38 Australian species/provenances in a randomized block design using 4 blocks (appendix iik). Replication of some species was prevented by shortage of seedlings. The number of seedlings planted per species ranged from 10-40. These details are omitted in the data summary but were included in survival assessment whose results are shown in Table 11. Other details included in the table are mean height and diameter. Species are rated in ascending order of height. Table 11 shows that eucalyptus performed better than acacias in both height and diameter. There was no consistent trend on survival.

To facilitate graphical comparison of species performance, species with survival of 40% and above were extracted from Table 11 and growth in height and diameter were illustrated in Figure 10. From this figure, species with promising potential are *Eucalyptus melanophloia, E. microtheca, E. intertexta, Acacia stenophylla, A. holosericea, A. salicina, Eramophilla bignoniflora* and *A. aneura* (13720) in declining order of growth potential.

4.5.3: Central American species trials

The species tested in the two trials are shown in Table 12. Mean height and diameter are shown in Figures 11a and b. The survival was high (Table 12). Compared to *E. camaldulensis, Melia volkensii* and *Grevillea robusta*, the mean height and diameter of central American species was lower. However, the trials are relatively young and potential of Central American species not yet well known. This observation justifies further monitoring of these trials. It is also noted from the two figures that mean annual growth of all the species is remarkable. Since the difference between the two trials was 1.5 years the results suggests that the tested species are fast growing.

4.6: VOLUME EQUATIONS FOR *E. CAMALDULENSIS* AT GATEGI AND MURAMBA

Spearmans' correlation analysis revealed greater coefficients between volume and height than that observed between volume and diameter (Table 13). The poor correlation of volume and diameter could be associated with the juvenile stage of assessed stands. This is based on the observation that the correlation coefficients between volume and measured parameters are greater for a 14-years stand (Gategi) than for an 8-year's plantation at Muramba.

Close spacing that lead to thin stems at Muramba could be the other factor that affected diameter growth. This may have lead to the poor correlation between DBH and volume.
Selected equations are:

(a) Gategi $V=-0.3617-0.0385d-0.0192h+0.0029hd$ ($R^2=0.78$)
(b) Muramba $V=-0.0039+0.0079h$ ($R^2=0.74$)

D and h are diameters at breast height (DBH) and heights of trees respectively. R^2 is the correlation coefficient between predicted and actual volumes. It was not possible to establish a reliable equation for *E. microtheca*.

Although the volume can be predicted with above equations for *E. camaldulensis* at Gategi and Muramba it should be noted that:

(a) Their precision is unsatisfactory because all the provenances were bulked together due to scarcity of data per provenance

(b) These equations are interim and are applicable for present age of assessed stands because relationship between volume and growth parameters would change with age.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.0 Adaptability of species within sites

The broad objective of trials in each site was to identify species that could provide specific or a variety of forestry goods and services based on growth and survival. However, in screening studies, survival can override growth. This is because survival is always dependent on uncontrollable site factors while growth be manipulated through management. Secondly, growth can also be relative depending on the intended use of tree crops. For example, eucalyptus may be preferred for bole production while species like *L. leucocephala* could be chosen for fodder production, which if periodically harvested may lead to higher biomass production.

Because of such considerations, the recommendation of species per site is based on a survival of 40% and above. MAI in height and diameter are also provided for evaluation of possible end products. Trees with greater MAI in height would be appropriate for pole production while species whose DBH growth potential is greater than height growth potential are likely to have an advantage in forage production. Such forage could be utilized as fodder or in production of manure. On the basis of the above criteria, the species recommended for specific sites are listed below.

GATEGI

All the species tested at Gategi had achieved a survival of 40% and above except for *B. aegyptiaca, E. alba, E. oleaza* and *G. robusta* (appendix III). Growth of *A. indica, A. seyal* and *A. senegal* was observed to be poor. Therefore, this assessment recommends all the tested species except those listed above. The MAI in height and DBH are provided in Table 4 for quick comparison of species or provenances. The great differences observed in height growth among provenances of *E. camaldulensis* and *E. microtheca* suggests the need to identify the appropriate provenance for specific sites other than making arbitrary choices based on species. This could be achieved through screening of potential provenances in a given site.

KATHWANA

At Kathwana various exotic species can be eliminated from their poor survival (Table 5). Surprisingly, *Senna atomaria*, a relatively new species was found to be highly adaptable, as revealed by its high survival of 100%. The species recommended for this site are shown in Table 15. Survival and MAI for height and DBH are included for comparison of species performance.

LANCIATHURIO

The species recommended for Lanciathurio are shown in Table 16. If the species or provenance was tested in several experiments, the mean MAI and survival obtained from those trials is used e.g. in *A. anuera* and *A. quachepele*.

MURAMBA

At Muramba, it was only *E. camaldulensis* provenances that were tested. Since the DBH was insignificant among the tested provenances, the selection of appropriate provenances was based on height. From Figure 9, it is recommended that provenances with positive % height deviation on height. From Figure 9, it is recommended that provenances with positive % height deviation from the population mean be considered as suited for this site. These provenances require close monitoring to determine if the current growth vigour will be maintained. Appendix V lists the provenances in order decreasing adaptability based on height growth. The best 2 provenances identified in this site were provenances indicated by Batch numbers 14379 and 14321.

NKANDO

The species recommended for Nkando are shown in Table 17. For the species that were tested in more than one trial, the mean for such trials is presented for MAI and survival. This was particularly applicable to the 1988 and 1989 species trial that were dominated by Central American species.

5.1 Adaptability of species across sites

Although there were several species and provenances tested, their adaptability across sites could not be evaluated. This is because such an objective was not included in the initial design. Therefore species and/ or provenances were not uniformly replicated across the sites and the few that were planted in more than one site were not subjected to similar treatments. For, example the Mean Annual Increment (MAI) in the height of *M. volkensii* (Table 14) may suggest an increasing site limitation from Kathwana, Lanciathurio and Nkando in that order. However, it was observed that *M. volkensii* trees at Kathwana were pruned, a treatment that was not administered in other sites. Pruning in this site was an initiative by the plot attendant. Secondly, it was not indicated whether the provenances grown in the 3 sites were the same or different. A third confounding factor was spacing which differed among the 3 sites (Table 3) and could have influenced growth and survival because of varied competition effects.

The above observation notwithstanding, variation in isolated or interactive site factors cannot be ignored. This is illustrated by the consistently lower MAI in height of *M. volkensii* and *P. dulce* at Nkando (Table 14). This suggests that site conditions at Nkando were harsher for the two species than in the other two sites.

Since the number of screened species and provenances was large, adaptability of species across the sites should be narrowed to those that are identified as having great potential in specific sites. This potential should be a compromise of height growth and survival because they were the major screening variables. On the basis of these variables, species identified as having exceptional potential include exotics like *A. auriculiformis, A. salicina, E. camaldulensis, E. microtheca, P. dulce* and *S. atomaria*. *M. volkensii* was the only indigenous species tested in several sites and was found to be widely adapted except at Nkando where survival was low (Tables 11 and 12).

5.2: Conclusion

From these trials, it was evident that potential benefits exist in selecting appropriate provenance for a given site. This was clearly illustrated by great variation observed in provenance variation of *E. camaldulensis* at Gategi, Lanciathurio and Muramba. Variation among *A. auriculiformis* at Lanciathurio and that of *E. microtheca* at Gategi was consistent with this observation.

Although the site conditions were varied, baseline data of site conditions in terms of actual rainfall, temperature and soils characteristics was missing. This limits extrapolation of present findings to other sites. Therefore, there is need to collect baseline data on soils and other climatic factors to facilitate comparison of trial sites with other areas where species identified in these trials could be extended to.

Except in land reclamation activities, a spacing of less than 3*3m is not appropriate for forestry trees. The close spacing used in most trials could have contributed to higher mortality because of competition. It is therefore recommended that all the trials be thinned to a minimum of 3*3m. The recommended spacing is interim and is subject to revision with age of each stand.

Figure 1: Approximate geographical location of Embu, Meru and Isiolo Districts in Kenya and the location of trial sites within the Districts.

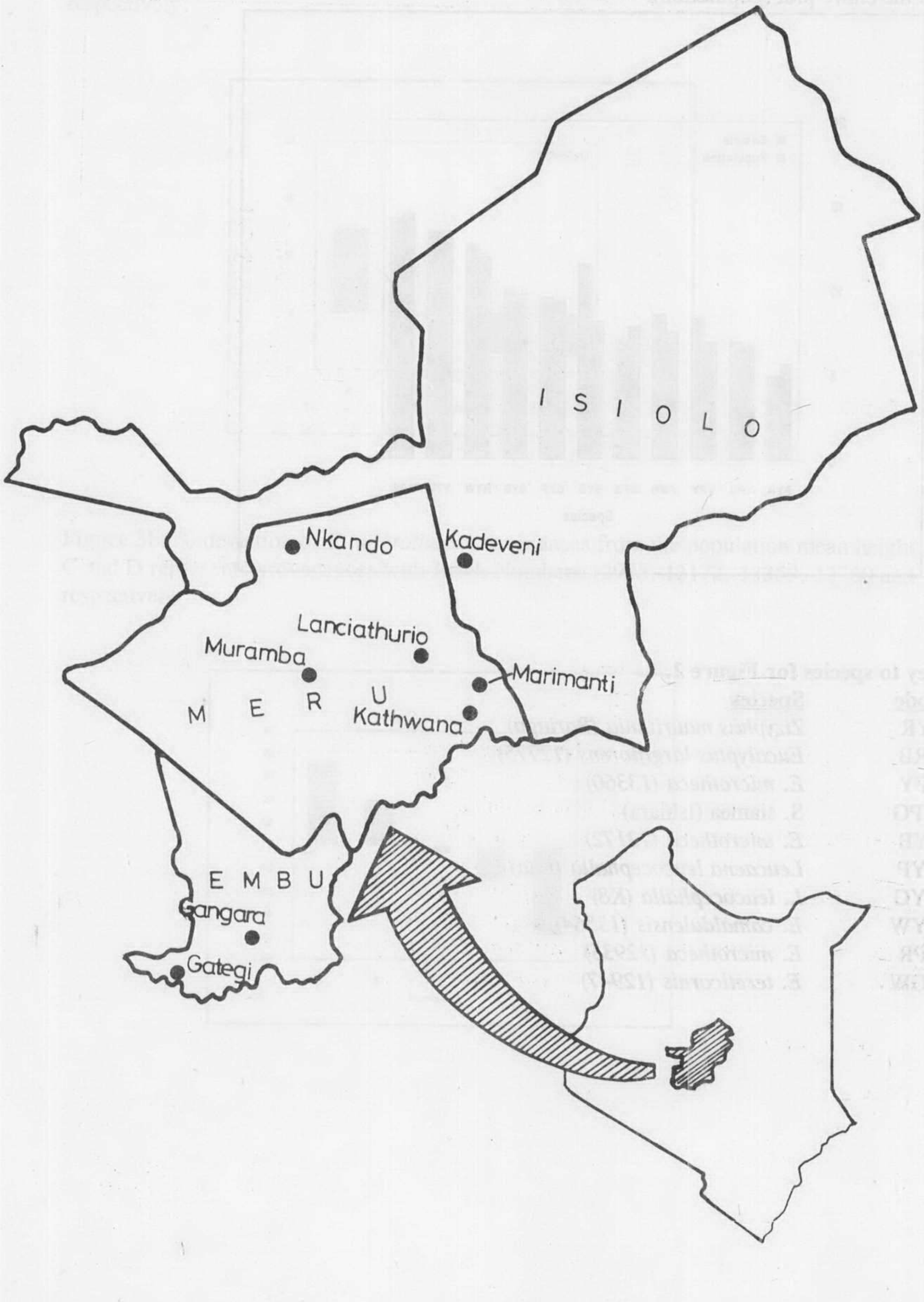
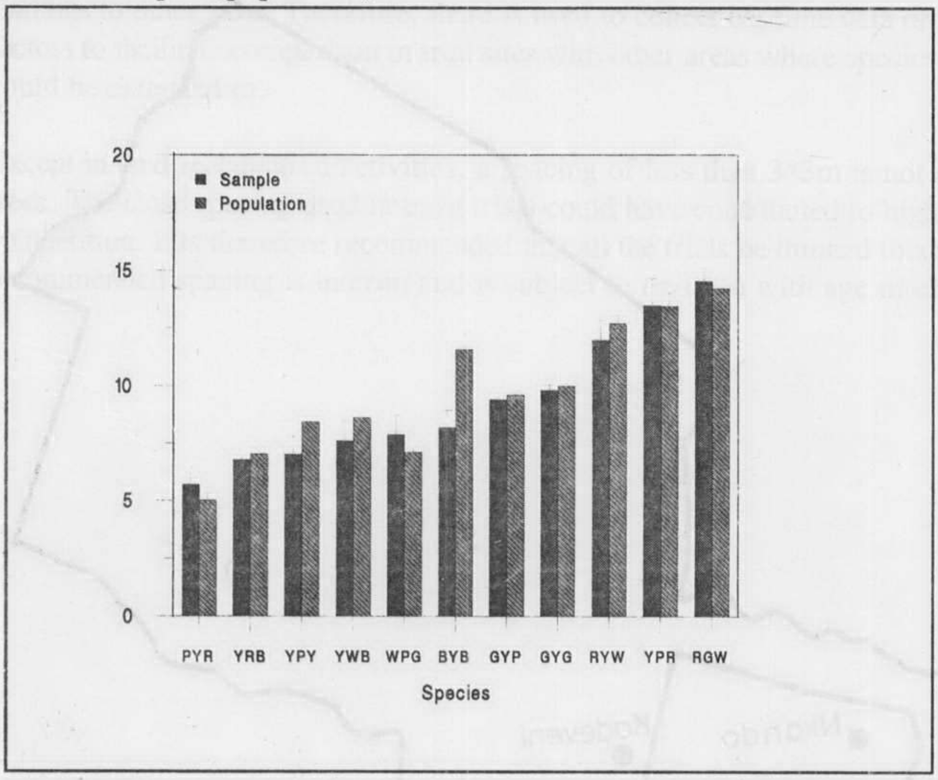


Figure 2: Sample and population mean height of selected species from the Gategi Trial of 1984. The figure reveals insignificant difference between mean height of 4 inner trees (sample) and the entire plot (population).



Key to species for Figure 2.

Code	**Species**
PYR	*Zizyphus mauritania (Baringo)*
YRB	*Eucalyptus largiflorens (12775)*
YPY	*E. microtheca (13360)*
WPG	S. siamea (Ishiara)
BYB	*E. microtheca (12172)*
GYP	*Leucaena leucocephalla (Ena)*
GYG	*L. leucocephalla (K8)*
RYW	*E. camaldulensis (13564)*
YPR	*E. microtheca (12935)*
RGW	*E. tereticornis (12947)*

Figure 3a: % deviation of *E. camaldulensis* provenances from the population mean height. A, B, C and D represents provenances with Batch Numbers 12964, 13433, 12352 and 12346 respectively.

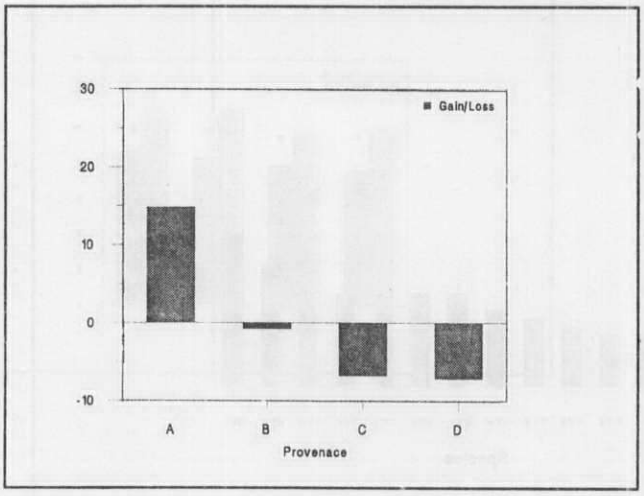


Figure 3b: % deviation of *E. microtheca* provenances from the population mean height. A, B, C and D represents provenances with Batch Numbers 12935, 12172, 13359, 13360 and 12524 respectively.

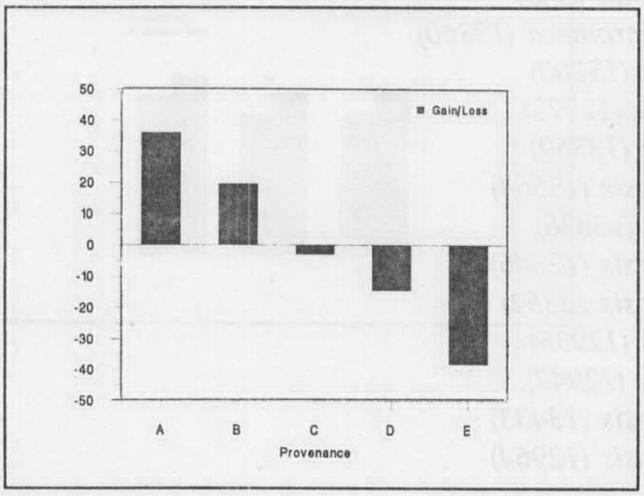
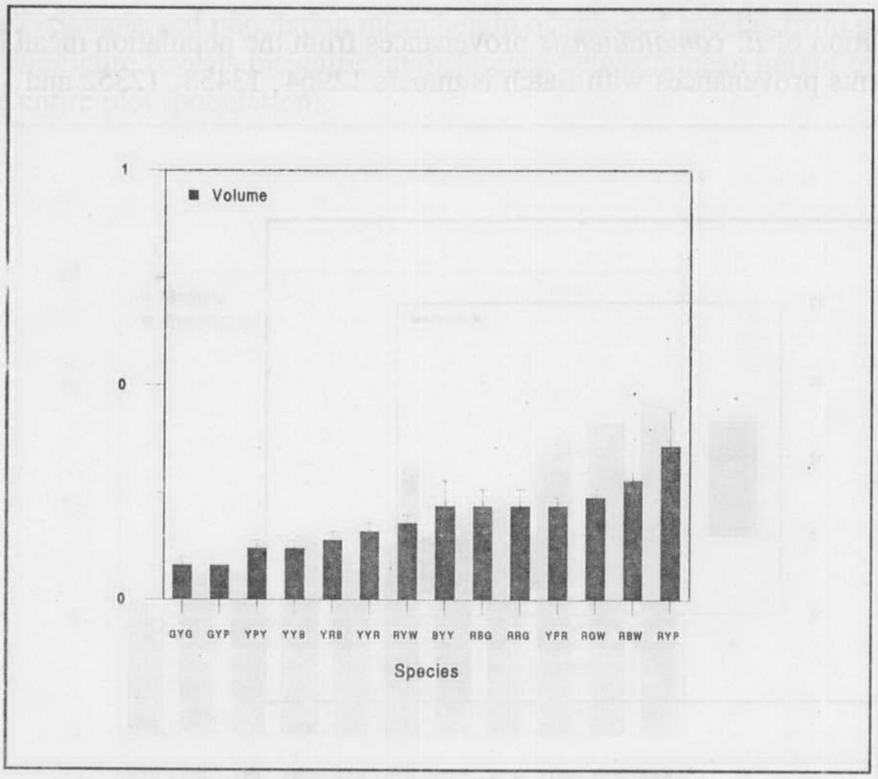


Figure 4: Mean tree volume of selected species from Gategi trial that was established in 1984.



Key to species for figure 4

Code	Species
GYG	*Leuceana leucocephalla (K8)*
GYP	*L. Leucocephalla (Ena)*
YPY	*Eucalyptus microtheca (13360)*
YYB	*E. microtheca (13200)*
YRB	*E. largiflorens (12775)*
YYR	*E. microtheca (13359)*
RYW	*E. camaldulensis (13564)*
BYY	*E. citriodora (13628)*
RBG	*E. camaldulensis (12346)*
RRG	*E. camaldulensis 12352)*
YPR	*E. microtheca (12935)*
RGW	*E. tereticornis (12947)*
RBW	*E. camaldulensis (13433)*
RYP	*E. camaldulensis (12964)*

Figure 5a: Mean height and dbh of *M. volkensii* provenance. The trial was established in November 1989 at Kathwana. The provenances were obtained from Kalulini (Kal), Voi, Mbololo (Mbo) and Gangara (Gan). Numbers above the bars indicate the number of trees in the sample.

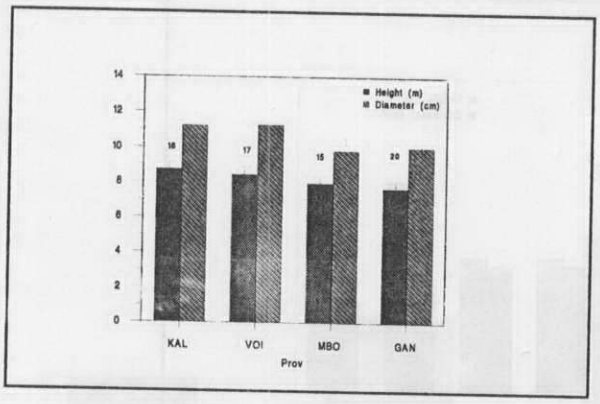


Figure 5b: Mean height and dbh of *M. volkensii* provenance. The trial was established in November 1989 at Kathwana. The provenances were obtained from Gangara (A) while B and C were from Kaunguni. Numbers above the bars indicate the number of trees in the sample.

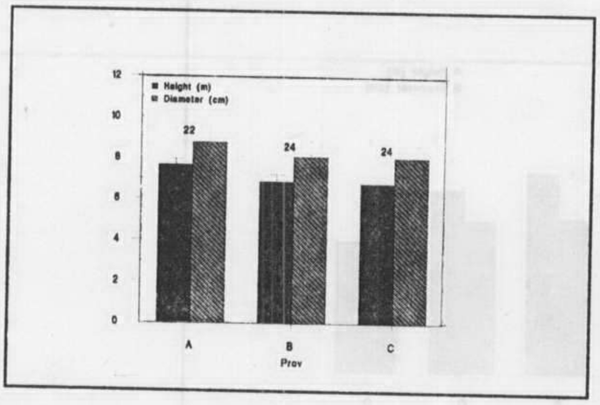


Figure 6: Mean height and diameter of *G. sepium* (A), *E. microtheca* (B), *S. atomaria* (C), *Entorolobium cylocarpus* (D) and *A. indica* (E) for an exotic species trial established at Kathwana in November 1989.

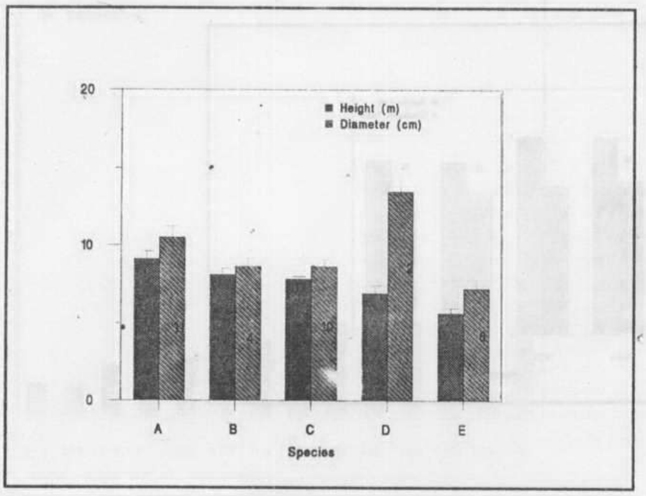


Figure 7: Mean height and dbh of *C. sinensis* (A), *T. brownii* (B), *D. melanoxylon* (C) and *T. indica* (D) for an indigenous species trial established at Kathwana in November 1989.

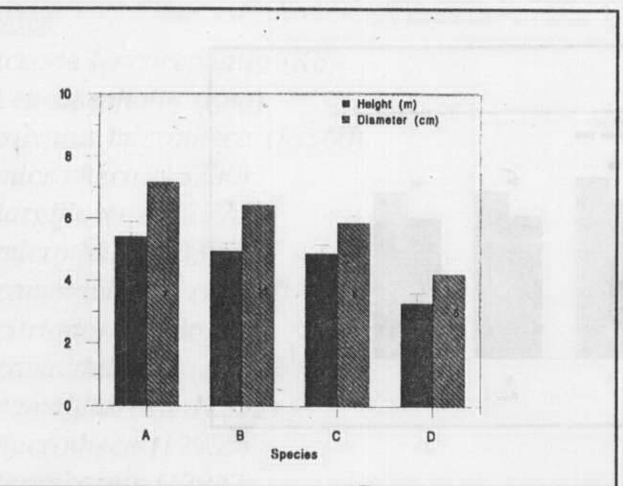


Figure 8: Mean height of the shortest, intermediate and tallest provenances of *E. camaldulensis* provenances established at Muramba in 1990.

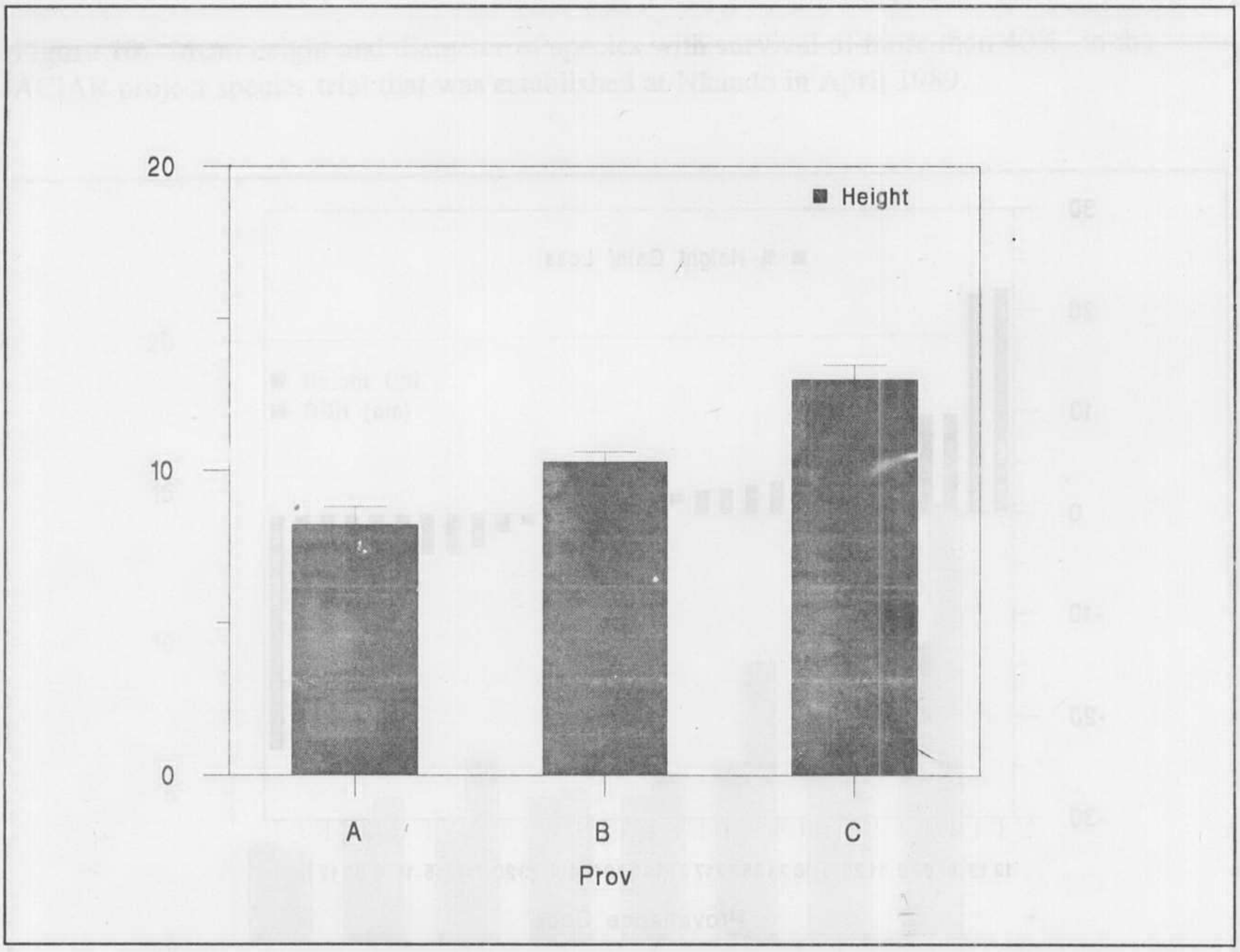


Figure 9: Percentage deviation of provenace mean height from the provenaces mean for the Muramba trial. The trial was established in 1990. The seed batch numbers of tested provenaces are shown in appendix V

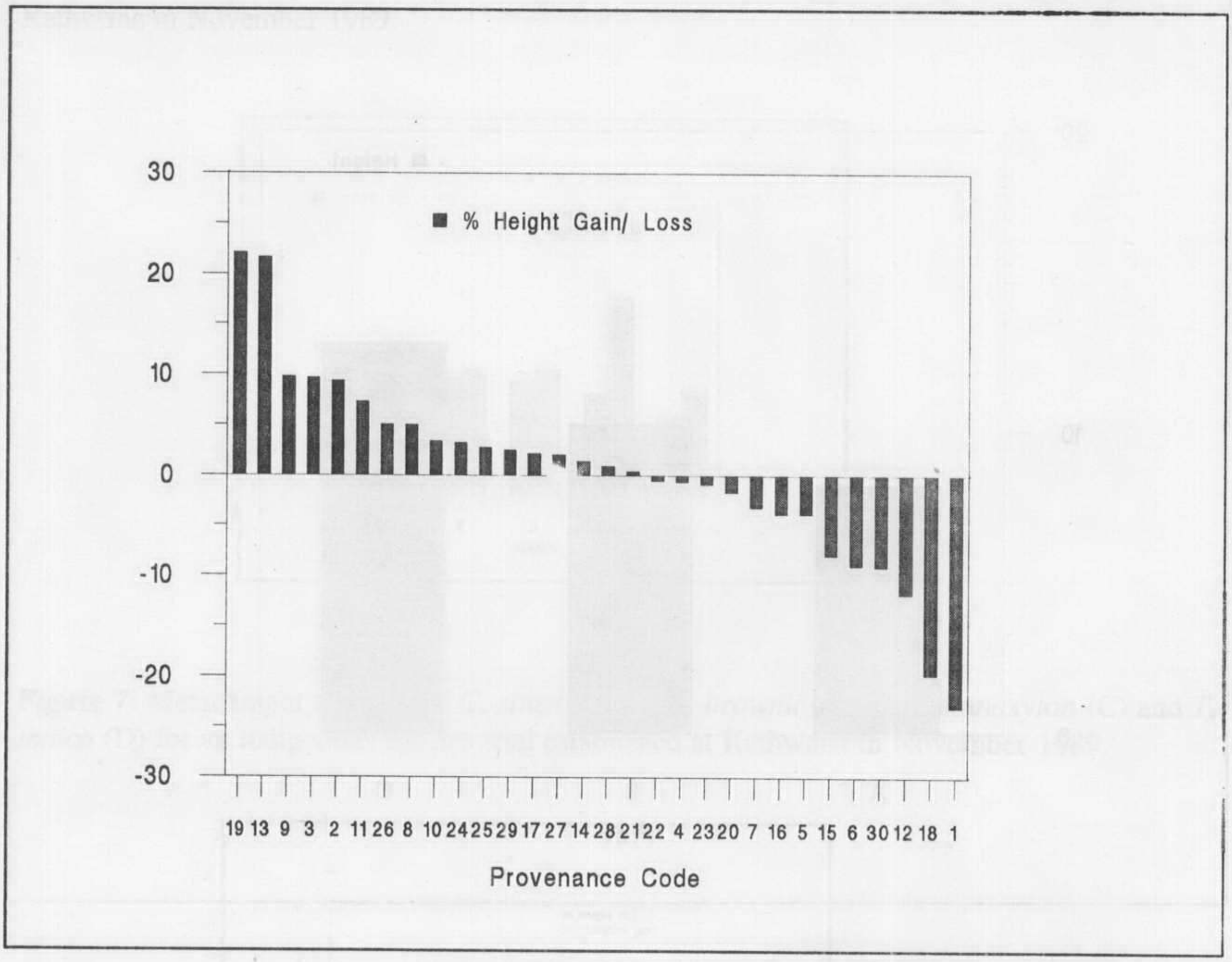
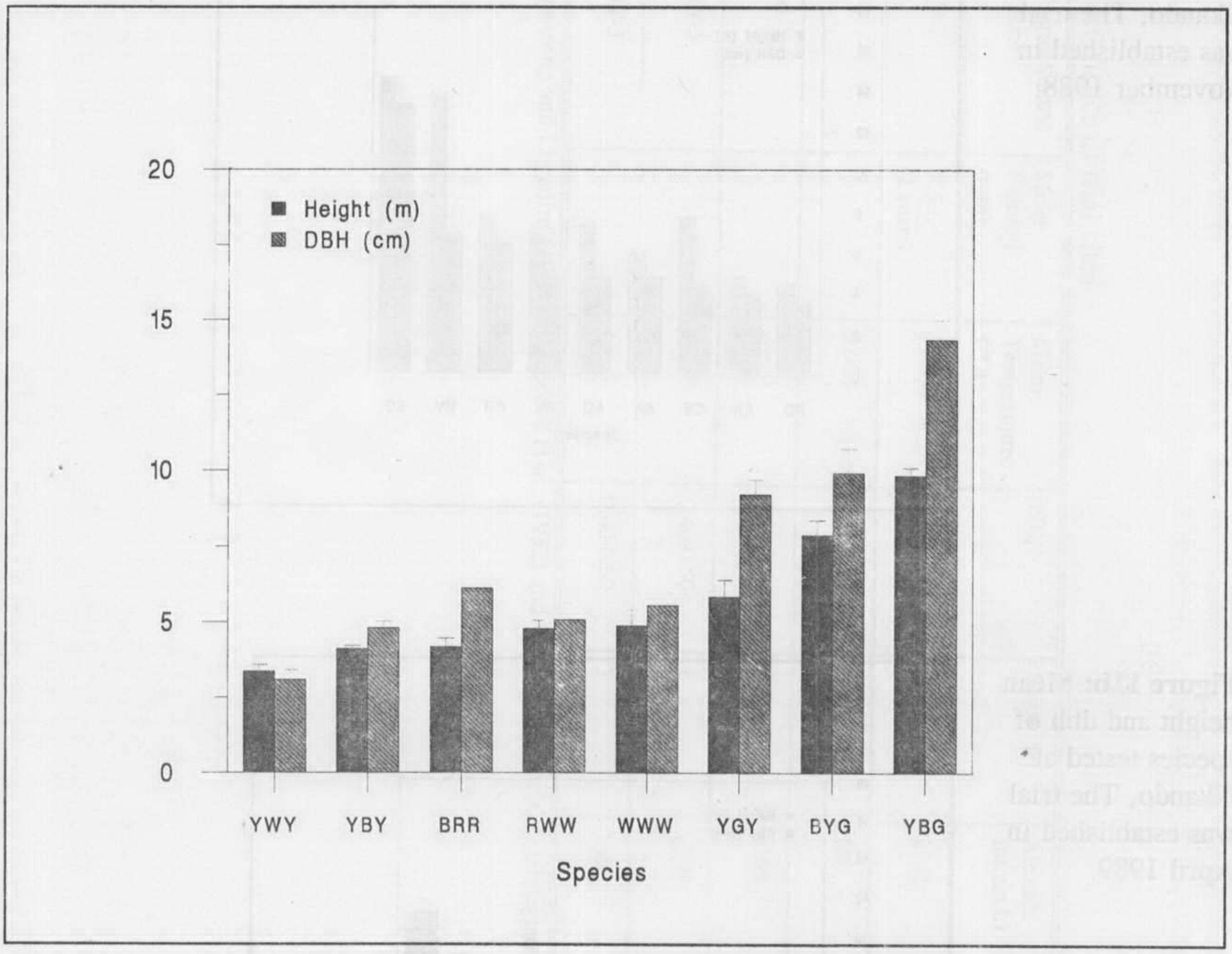


Figure 10: Mean height and diameter of species with survival of more than 40% in the ACIAR project species trial that was established at Nkando in April 1989.



Key to Species for figure 10

Code	Species
YWY	*Acacia anuera*
YBY	*Eramophilla bignoniflora*
BRR	*Acacia salicina*
RWW	*Acacia holosericea*
WWW	*Acacia stenophylla*
YGY	*Eucalyptus argillacea*
BYG	*Eucalyptus microtheca*
YBG	*Eucalyptus melanophloia*

Figure 11a: Mean height and dbh of species tested at Nkando, The trial was established in November 1988.

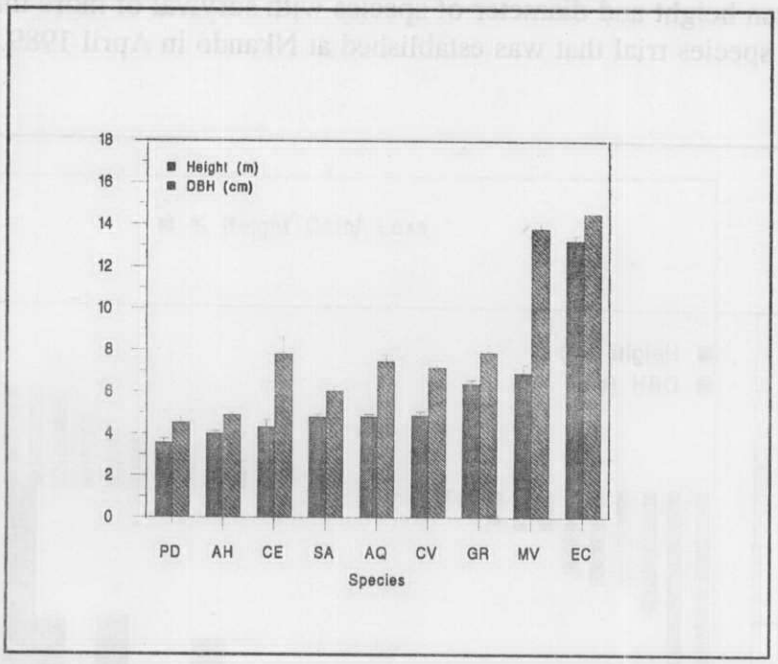
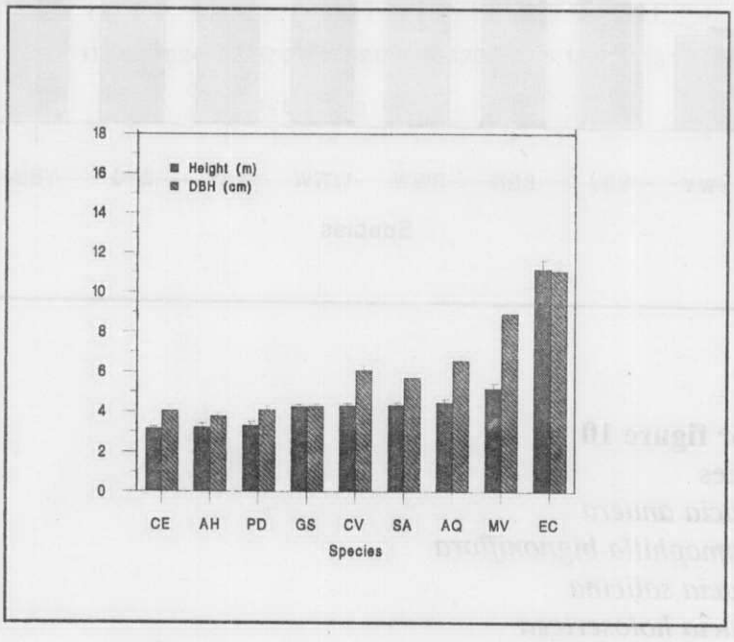


Figure 11b: Mean height and dbh of species tested at Nkando, The trial was established in April 1989.



The tested species were *Ateleia herbertsmithii* (AH), *Albizia guachapele* (AQ), *Caesalpinia eriostachys* (CE), *Caesalpinia velutina* (CV), *Eucalyptus camaldulensis* (EC), *Gliricidia sepium* (GS), *Grevillea robusta* (GR), *Melia volkensii* (MV), *Pithecelobium dulce* (PD) and *Senna atomaria* (SA)

Table 1: Characteristics of trial sites

Site	Agroclimatic Zone	Mean Rainfall (mm)	Mean Temperature (°C)	r/E$_o$	Slope (%)	Altitude (m.a.s.l.)	Geographic Position	Vegetation Type	Soil Type
Gategi	V-2	715.5 (2 years)	22-24	0.25-0.40	2	1140	0° 45'S 37° 25'E	Bushed Grassland	Chromic Vertisols
Kathwana	V		22-24	0.25-0.40	-	720	0° 20'S 37° 53'E	Acacia/ Commiphora	Chromic Luvisols
Lanciathurio	V		24-30	0.25-0.40	7.5	1160	0° 17'N 37° 43'E	Acacia/ Commiphora	Humic Nitisols
Muramba	IV-5		16-18	0.40-0.50	1	1300	0° 12'N 37° 41'E	Savannah	Humic Nitisols
Nkando	IV-5		16-18	0.40-0.50	3	1600	0° 13'N 37° 46'E	Wooded Grassland	Verto-luvic Phaeozems

Adopted from Armstrong and Lugadiru (1986), Sombroek et al. (1982) and Undated EMI trial Establishment Reports.

Table 2: Summary of land preparation and protection of research plots per site.

Site	Land preparation method	Maintenance
Gategi	Tractor-ploughing and deep-ripping with bulldozer	Spot weeding to a radius of 0.5m from the seedling and slashing of bushes in other area.
Kathwana	Ox-ploughing	Complete weeding of the plot.
Lanciathurio	Tractor-ploughing	Complete weeding and use of herbicides. Trees intercropped with beans in early stages.
Muramba	Tractor-ploughing	Complete weeding of the plot. Trees intercropped with beans in 1990 and 1991.
Nkando	Tractor-ploughing	Complete weeding. Trees intercropped with beans before canopy closure.

Table 3: Summary of experimental details.

Site	Layout	Establishment year/s	No. of Trials	Spacing (m)
Gategi	Square plots	1983/84	1	2.5*2.5
Kathwana	Line plots	1989	3	3*3
Lanciathurio	Line plots	1988, 1989 and 1990	4	1.5*2.5 & 2*4
Muramba	Square plots	1990	1	3*3
Nkando	Line plots	1988 and 1989	3	1.25*2.5

All the trails were established using randomized block design and had 3-5 replicates

Table 4: Mean height and dbh and corresponding mean annual increment (MAI) for species tested at Gategi. The trial was established in December 1984.

Species	Code	Batch No.	Hgt	MAI	Dbh	MAI
E. maculata	YRW	6164	17.17	1.23	10.67	0.76
E. citridora	RPG	12939	16.63	1.19	13.08	0.93
E. camaldulensis	RYP	12964	15.65	1.12	13.94	1.00
E. tereticornis	RGW	12947	14.29	1.02	12.24	0.87
E. microtheca	YPR	12935	14.19	1.01	15.29	1.09
E. camaldulensis	RBW	13433	13.52	0.97	14.28	1.02
E. camaldulensis	RYW	13564	12.94	0.92	11.98	0.86
E. camaldulensis	RRG	12352	12.70	0.91	11.20	0.80
E. camaldulensis	RBG	12346	12.65	0.90	10.85	0.78
E. microtheca	BYB	12172	12.48	0.89	12.30	0.88
E. citriodora	BYY	12628	12.36	0.88	10.01	0.71
E. astrigens	RPY	12842	12.35	0.88	12.14	0.87
E. occidentalis	YYY	9902	11.36	0.81	12.27	0.88
E. microtheca	YYR	13359	10.12	0.72	10.80	0.77
L. leucocephala	GYG	K8	10.04	0.72	9.32	0.67
L. Leucocephala	GYP	Ena	9.61	0.69	9.14	0.65
E. microtheca	YPY	13360	8.93	0.64	9.07	0.65
E. polpunea	YWB	11733	8.32	0.59	8.68	0.62
E. salmonophloia	YYP	9919	8.21	0.59	26.91	1.92
E. occidentalis	BYG	12476	8.09	0.58	10.51	0.75
E. largiflorens	YRB	12775	7.84	0.56	8.25	0.59
S. siamea	WPG	Ishiara	7.23	0.52	8.38	0.60
E. microtheca	YPB	13200	7.21	0.52	6.76	0.48
P. juliflora	GGY	-	7.19	0.51	6.56	0.47
A. nilotica	-	-	6.88	0.49	11.33	0.81
E. microtheca	YPG	12524	6.46	0.46	7.34	0.52
E. alba	RPR	12993	5.97	0.43	6.37	0.45
E. oleosa	YYB	9910	5.56	0.40	4.29	0.31
Z. mucronata	PYY	Baringo	5.53	0.39	5.22	0.37
A. pendula	BWR	13482	5.53	0.39	7.72	0.55
C. glauca	WRB	13137	5.50	0.39	5.10	0.36
B. aegyptiaca	B	Mutonga	5.47	0.39	11.66	0.83
P. julifora	GWY	-	5.23	0.37	4.68	0.33
Z. mauritania	PYR	Baringo	4.85	0.35	4.47	0.32
A. lebbeck	PWB	-	4.56	0.33	10.45	0.75
A. indica	A	Kinna	3.74	0.27	5.18	0.37
A. seyal	GWP	Isiolo	2.66	0.19	4.85	0.35
A. senegal	PWY	-	2.18	0.16	3.19	0.23

Table 5: Species tested in the exotic species trial at Kathwana

Species	Provenace	Batch No.	No. Planted	No. Surviving	Survival (%)
E. microtheca	Roe Ck. N.T.A.	17249	10	5	50.00
E. camaldulensis	Petford, QLD	15223	10	0	0.00
A. guachapele	Motagua v, Guatemala	56/87	10	0	0.00
A. lebbeck	Shedi Sudan	N/A	10	0	0.00
E. cyclocarpus	J. de Otoro Honduras	21/83	10	2	20.00
S. atomaria	Comayagua Honduras	25/83	10	10	100.00
G. sepium	Mexico	38/85	20	11	55.00
P. aculeta	Isiolo Kenya	N/A	10	0	0.00
A. indica	Mombasa Kenya	N/A	10	6	60.00
A. anuera	N/A	N/A	10	0	0.00

Table 6: Species tested in Indigineous species trial at Kathwana

Species	Provenace	No. Planted	No. surviving	Survival (%)
C. sinesis	Isiolo	10	7	70.00
D. melanoxylon	Kibwezi	10	9	90.00
T. indica	Tharaka	5	5	100.00
T. brownii	Tharaka	10	10	100.00

Table 7: Mean height, diameter and survival of Australian species at Lanciathurio after 10 years. Bolded row shows the median height of *Acacia* species.

Species	Batch No	Height (m)	Diameter (cm)	MAI Height	MAI Diamter	No. Planted	No. Surviving	Survival (%)
A. pachycarpa	15749	2.27	3.58	0.23	0.36	30	8	26.67
A. trachycarpa	15767	2.8	4.47	0.28	0.45	30	16	53.33
A. victoriae		3.43	5.4	0.34	0.54	30	11	36.67
A. ampliceps	15702	3.85	5.05	0.39	0.51	30	4	13.33
A. sclerosperma	15774	4.05	5.93	0.41	0.59	30	18	60.00
Acacia eriopoda	**17164**	**4.65**	**4.9**	**0.47**	**0.49**	**30**	**8**	**26.67**
A. maconchiena	14747	4.69	6.55	0.47	0.66	30	11	36.67
A. tolurosa	17490	5.1	5.4	0.51	0.54	30	4	13.33
A.stenophylla	17497	5.46	5.81	0.55	0.58	30	26	86.67
A. holosericea	14651	5.73	4.58	0.57	0.46	30	16	53.33
A. julifera	14974	5.9	4.73	0.59	0.47	30	3	10.00
A. salicina	15465	6.2	10.86	0.62	1.09	30	23	76.67
A. auriculiformis	16147	6.62	7.08	0.66	0.71	30	4	13.33
A. holosericea	16389	6.7	7.76	0.67	0.78	30	6	16.67
A.plectocarpa	16187	6.83	7.77	0.68	0.78	30	3	10.00
A. aneura	13481	6.92	9.88	0.69	0.99	30	12	40.00
E. Microtheca	15944	12.28	15.64	1.23	1.56	30	13	43.33
E. camaldulensis	15223	13.24	14.03	1.32	1.40	30	10	33.33

Table 8: Mean height, diameter and survival of Australian species at Lanciathurio after 8 years. The bolded row represents the median height.

Species	Batch No.	Height (m)	Dimater (cm)	MAI Height	MAI Diamter	No. Planted	No. Surviving	Survival (%)
A. trachycarpa	16759	2.05	4.00	0.26	0.50	30	23	76.67
A. torulosa	17490	2.80	2.90	0.35	0.36	30	3	10.00
A. difficilis	16173	3.60	3.50	0.45	0.44	30	4	13.33
A. aulacocarpa	14969	3.63	3.48	0.45	0.44	30	6	20.00
A. ampliceps	15702	4.13	5.38	0.52	0.67	30	6	20.00
A. monticola	17333	4.20	2.60	0.53	0.33	30	2	6.67
G. pteridifolia	16747	4.20	4.45	0.53	0.56	30	11	36.67
A. aneura	13841	4.25	4.27	0.53	0.53	30	12	40.00
A.eriopoda	17164	4.46	3.87	0.56	0.48	30	18	60.00
A. shirleyii	14625	4.48	4.30	0.56	0.54	30	6	20.00
A. ampliceps	15734	4.76	6.61	0.60	0.83	30	14	46.67
A.stenopylla	15750	4.80	4.88	0.60	0.61	30	10	33.33
A.brasii	15480	4.85	5.22	0.61	0.65	30	13	43.33
A. holosericea	14651	5.58	4.44	0.70	0.55	30	15	50.00
A. julifera	14974	5.60	4.90	0.70	0.61	30	2	6.67
A. plectocarpa	15727	6.00	5.65	0.75	0.71	30	6	20.00
A. holosericea	16389	6.04	5.57	0.76	0.70	30	9	30.00
G.robusta	**N/A**	**6.19**	**6.94**	**0.77**	**0.87**	**30**	**14**	**46.67**
A. auriculiformis	16151	6.36	6.31	0.80	0.79	30	18	60.00
E. melanophloia	17005	6.89	7.84	0.86	0.98	30	10	33.33
A. auriculiformis	16147	7.07	6.92	0.88	0.87	30	20	66.67
A.salicina	16648	7.14	9.30	0.89	1.16	30	14	46.67
A. auriculiformis	16484	7.79	9.31	0.97	1.16	30	18	60.00
A. auriculiformis	16610	8.30	9.13	1.04	1.14	30	7	23.33
E. camaldulensis	12344	8.47	9.50	1.06	1.19	30	26	83.33
E.europhylla	14531	9.35	9.89	1.17	1.24	30	10	33.33
E.tereticornis	12965	9.36	9.14	1.17	1.14	30	21	70.00
E.europhylla	13011	9.79	10.33	1.22	1.29	20	8	40.00
E. camaldulensis	14338	10.09	11.34	1.26	1.42	30	24	80.00
E. camaldulensis	12187	10.24	11.70	1.28	1.46	30	25	83.33

Table 9: Height, diameter and survival of species tried at Lanciathurio at the age of 11 years.

Species	Batch No.	Height (m)	Diamter (cm)	MAI Height	MAI Diameter	No. Planted	No. Surviving	Survival (%)
A. indica		0.82		0.07		30	4	13.33
L. eriocalyx		1.13		0.10		30	9	30.00
C. sinensis		4.66	6.79	0.42	0.62	30	25	83.33
P. dulce		4.90	6.41	0.45	0.58	30	20	66.67
P. pallida		5.72	8.03	0.52	0.73	30	9	30.00
A. guachepele		5.82	8.98	0.53	0.82	30	17	56.67
P. juliflora		6.63	8.34	0.60	0.76	30	22	73.33
A. holosericea	17165	7.01	7.38	0.64	0.67	30	15	50.00
C. velutina		8.09	10.56	0.74	0.96	30	18	60.00
M. volkensii		8.92	15.98	0.81	1.45	30	9	30.00
E. camaldulensis	15223	9.61	13.80	0.87	1.25	30	16	53.33
E. camaldulensis	15235	9.96	13.61	0.91	1.24	30	16	53.33

Table 10: Height, diameter and survival of Lanciathurio mixed species trial after 10 years.

Species	Height (m)	Diameter (cm)	MAI Height	MAI Diameter	No. Planted	No. Surviving	Survival (%)
G. sepium	4.85	4.55	0.49	0.46	30	21	70.00
P. dulce	5.08	5.36	0.51	0.54	30	27	90.00
A. herbertsmith	5.1	5.06	0.51	0.51	30	23	76.67
S. atomaria	6.53	6.21	0.65	0.62	30	30	100.00
C. velutina	6.72	7.7	0.67	0.77	30	12	40.00
A. guachepele	7.15	9.27	0.72	0.93	30	12	40.00
S. siamea	7.72	8.81	0.77	0.88	30	19	26.67
E. camaldulensis	8.31	12.06	0.83	1.21	30	8	26.67

Table 11: Mean height, diameter and survival of species tested at Nkando for ACIAR project trial of November 1989. The species are recorded in ascending order based on height.

Species	Batch No.	Height (m)	Diameter (cm)	MAI Height	MAI Diameter	No. Planted	No. Surviving	Survival (%)
A. osnaldii	15560	1.9	3.00	0.21	0.33	40	4	10.00
E. cambageana	12937	3.13	4.62	0.35	0.51	40	14	35.00
A. victoriae	15559	3.24	3.3	0.36	0.37	40	12	30.00
A. aneura	13720	3.36	3.09	0.37	0.34	40	16	40.00
A. saligna	15791	3.88	6.27	0.43	0.70	40	6	15.00
E. bignoniflora	17212	4.11	4.8	0.46	0.53	40	38	95.00
A. salicina	15465	4.17	6.12	0.46	0.68	40	16	40.00
A. aneura	13481	4.7	4.23	0.52	0.47	40	4	10.00
A. holosericea	1465[illegible]	4.77	5.08	0.53	0.56	40	17	42.50
A. stenopylla	14670	4.87	5.55	0.54	0.62	40	30	75.00
E. leptophleba	15248	5.08	5.86	0.56	0.65	40	12	30.00
E. argillacea	13942	5.09	6.35	0.57	0.75	40	10	25.00
E. intertexta	17244	5.84	9.2	0.65	1.02	40	20	50.00
E. microtheca	15944	7.87	9.92	0.87	1.10	40	22	55.00
E. argophloia	15504	8.98	13.08	1.00	1.45	40	12	30.00
E. melanophloia	17005	9.83	14.33	1.09	1.59	40	16	40.00

Table 12: Survival (%) of Central American Species tested at Nkando in trials that were established in April 1989 and November 1988.

Species	1989 Planting			1988 Planting		
	No. Planted	No. Surviving	% Survival	No. Planted	No. Surviving	% Survival
A. herbertsmithi	25	21	84.00	30	17	56.67
A. guachepele	40	33	82.50	30	28	93.33
C. eriostachys	30	15	50.00	30	23	76.67
C. velutina	40	14	35.00	30	30	100.00
E. camaldulensis	40	32	80.00	30	24	80.00
G. sepium	-	-	-	30	23	76.67
G. robusta	40	29	72.50	-	-	-
M. volkensii	40	13	32.50	30	14	46.67
P. dulce	40	29	72.50	30	22	73.33
S. atomaria	40	35	87.50	30	30	100.00

Table 13: Spearman's correlation coefficients and associated probabilities showing relationship between tree volume and growth parameters (Height and dbh)

	Dbh	Height	Site	n	Species
Volume	0.037 Ns	0.74 (0.0001)	Muramba	259	*E. camaldulensis*
	0.55 0.01	0.79 (0.0001)	Gategi	18	*E. camaldulensis*
	0.36 Ns	0.54 (0.01)		20	*E. microtheca*
Height	0.026* Ns		Muramba	259	*E. camaldulensis*
	0.56 (0.02)		Gategi	18	*E. camaldulensis*
	0.56 (0.01)			20	*E. microtheca*

Table 14: Mean annual height (m) of *Melia volkensii* and *Pithecolobium dulce* at Kathwana, Lanciathurio and Nkando.

Species	Kathwana	Lanciathurio	Nkando
M. volkensii	0.85	0.81	0.63
P. dulce	0.44	0.51	0.36
Soil	C. luvisols	H. nitisols	V.l. phaeozems
Zone	V	V	V-5

Table 15: Species that are recommended for Kathwana

Species	% Survival	MAI-Height	MAI-dbh
G. sepium	55	1.01	1.17
M. volkensii	95	0.76-0.90	0.92-1.19
E. microtheca	50	0.90	0.96
S. atomaria	100	0.87	0.96
A. indica	60	0.63	0.80
C. sinensis	70	0.60	0.80
T. indica	100	0.55	0.71
D. melanoxylon	90	0.54	0.65
T. brownii	100	0.37	0.47

Table 16: Species recommeded for Lacnciathurio

Species	Batch No.	% Survival	MAI-Height	MAI-DBH
E. camaldulensis	12187	83.33	1.28	1.46
E. camaldulensis	14338	80.00	1.26	1.42
E. microtheca	15944	43.33	1.23	1.56
E. europhylla	13011	40.00	1.22	1.29
E. tereticornis	12965	70.00	1.17	1.24
E. camaldulensis	12344	83.33	1.06	1.19
A. auriculiformis	16484	60.00	0.97	1.16
E. camaldulensis	15235	53.33	0.91	1.24
A. salicina	16648	46.67	0.89	1.16
A. auriculiformis	16147	66.67	0.88	0.87
E. camaldulensis	15223	53.33	0.87	1.25
A. auriculiformis	16151	60.00	0.80	0.79
G. robusta	-	46.67	0.77	0.87
A. quachepele	-	40.00	0.72	0.93
C. velutina	-	50.00	0.71	0.87
S. atomaria	-	100.00	0.65	0.62
A. holosericea	14651	51.67	0.64	0.51
A. holosericea	17165	50.00	0.64	0.67
A. salicina	15465	76.67	0.62	1.09
A. brasii	15480	43.33	0.61	0.65
A. anuera	13841	40.00	0.61	0.76
A. ampliceps	15734	46.67	0.60	0.83
A. eriopoda	17164	60.00	0.56	0.48
A. stenophylla	17497	86.67	0.55	0.58
A. herbertsmith	-	76.67	0.51	0.51
G. sepium	-	70.00	0.49	0.46
P. dulce	-	78.34	0.48	0.56
C. sinensis	-	83.33	0.42	0.62
A. sclerosperma	15774	60.00	0.41	0.59
A. trachycarpa	15767	53.30	0.28	0.45
A. trachycarpa	16759	76.67	0.26	0.50

Table 17: Species recommended for Nkando

Species	Batch No.	% Survival	MAI-Height	MAI-dbh
E. Camaldulensis	-	80.00	1.22	1.28
E. melanophloia	17005	40.00	1.09	1.59
E. microtheca	15944	55.00	0.87	1.10
E. intertexta	17244	50.00	0.65	1.02
G. robusta	-	72.50	0.64	0.79
A. stenophylla	14670	75.00	0.54	0.62
A. holosericea	14651	42.50	0.53	0.56
A. quachepele	-	87.92	0.47	0.71
S. atomaria	-	93.75	0.46	0.62
E. bignoniflora	17212	95.00	0.46	0.53
C. velutina	-	67.50	0.46	0.67
A. salicina	15465	40.00	0.46	0.68
G. sepium	-	76.67	0.43	0.43
C. eriostachys	-	63.34	0.38	0.60
A. anuera	13720	40.00	0.37	0.34
A. herbertsmithi	-	70.34	0.36	0.44
P. dulce	-	72.92	0.35	0.43

References

Armstrong, G.D. and Lugadiru, J.K. 1986. Embu-Meru-Isiolo Programme, Kenya Forestry Project Report.

Kramer, P. J. 1986. Role of Physiology in forestry. Tree Physiol. 2: 1-16.

Levitt, J. 1980. Plants responses to environmental stresses. Vol 2. Water, Radiation and Other Stresses.

Sombroek, W.G., Braun, H.M.H. and Van der Pouw, P.J.W. 1982. Exploratory soil map of Kenya and Agroclimatic zones. Exploratory soil report No. E1. Kenya Soil Survey Nairobi 56pp. ISBN 90-327-0162-2.

Appendix Ia: Results of Central American species trial at Gangara. the trial was established in November 1988

Species	No planted	No. Surviving	% Survival	Height	MAI	Dbh	MAI
C. velutina	30	10	33.33	7.6	0.69	10.8	0.98
A. quachepele	30	12	40.00	9.6	0.87	15.6	1.42
A. herbertsmith	30	11	36.67	6.6	0.60	6.7	0.61
L. eriocalyx	30	11	36.67	7.6	0.69	8.0	0.73
G. sepium	30	16	53.33	5.3	0.48	5.8	0.53

Appendix Ib: Results of Kadevene ACIAR project trial of November 1990.

Species	No. Planted	No. Surviving	% Survival	Height	MAI	Dbh	MAI
A. victoriae	30	8	26.67	2.3	0.29	4.0	0.50
C. cristata	40	24	60.00	3.4	0.43	3.2	0.40
E. camaldulensis	40	4	10.00	3.2	0.40	2.9	0.36
E. camaldulensis	30	2	6.67	2.7	0.34	2.5	0.31
E. melanophloia	40	4	10.00	3.3	0.41	3.6	0.45
E. tereticornis	40	5	12.50	3.5	0.44	3.7	0.46
G. sepium	10	7	70.00	2.2	0.28		
M. bracteata	40	26	65.00	2.2	0.28	2.8	0.35

Appendix Ic: Results of ACIAR project trial at Marimanti. The trial was established in November 1989.

Species	No. Planted	No. Surviving	% Survival	Height	MAI	DBH	MAI
E. camaldulensis	16	5	31.25	14.1	1.57	16.5	1.83
E. chippendalei	24	15	62.25	10.4	1.16	13.9	1.54
E. microtheca	16	6	37.50	11.1	1.23	15.2	1.69
E. odontocarpa	16	1	6.25	7	0.78	8.4	0.93

Appendix Id: Results of ACIAR species trial of November 1989 at Kadeveni.

Species	No. Planted	No. Surviving	% Survival	Height	MAI	DBH	MAI
A. georgine	20	15	75.00	2.2	0.24	3.7	0.41
A. harpophylla	40	25	62.50	2.5	0.32	3.3	0.37
A. maconchiena	20	7	35.00	3.1	0.34	4.4	0.49
A. oswaldii	30	3	10.00	1.9	0.21		
A. pachycarpa	40	25	62.50	3	0.33		
A. salicina	40	7	17.50	3.1	0.34	5.9	0.66
A. stenophylla	30	11	36.67	3.6	0.40	5.2	0.58
A. stenophylla	30	8	26.67	4.8	0.533	4.9	0.54
A. latescens	40	1	2.50	2.6	0.29	4.2	0.47
A. victoriae	40	2	5.00	2.2	0.24	2.9	0.32
C. cristata	20	3	15.00	3.3	0.37	4.5	0.50
E. bignoniflora	20	9	45.00	3.2	0.36	4.4	0.49
E. argillacea	40	2	5.00	3.1	0.34	3.3	0.37
E. argophloia	40	4	10.00	4.6	0.51	5.6	0.62
E. cambageana	20	5	25.00	3.6	0.40	6.7	0.74
E. intertexta	30	5	16.67	1.3	0.14	2.2	0.24
E. leptophloia	40	12	30.00	4.0	0.44		
L. cunnighammi	20	3	15.00	3.3	0.37	3.5	0.39

Appendix II (a)
List of species tested at Gategi.

CODE	SPECIES	PROVENANCE /Batch No.
RYP	Eucalyptus camaldulensis	Petford, QLD /12964
RBG	Eucalyptus camaldulensis	Kimberly, WA/12346
RBW	Eucalyptus mircrotheca	Wiluna, WA/13433
BYB	Eucalyptus microtheca	Walgett, NSW/12172
GYP	Leucaena leuccephala	Ena
YPG	Eucalyptus microtheca	De Grey R. WA/12524
WBP	Atriplex Nummularia	Setropa
PRY	Ziziphus mauretiana	Kositei
YPY	Eucalyptus microtheca	Laura R. QLD/13360
WGB	Azadarachta indica	Mombasa
RPR	Eucalyptus alba	Mt. Molly QLD/12993
YWB	Eucalyptus populnea	Quilpie QLD/11733
GYG	Leucaena leucocephala	K8
PGW	Acacia nilotica	Timmers + Leyer
RGW	Eucalyptus tereticornis	Kennedy QLD/12947
RYW	Eucalyptus camaldulensis	Gilbert QLD/13564
WPP	Acacia polyacantha	Siakago
YPRf	Eucalyptus microtheca	Charleville QLD/12935
WPG	Cassia siamea	Ishiara
PYY	Ziziphus mucronata	Kositei
WBW	Atriplex semi-baccata	Setropa
WGR	Parkinsonia aculeata	Isiolo
BYY	Eucalyptus citriodora	Gornett QLD/13628
YRB	Eucalyptus largiflorens	Wilcannia NSW/12775
BYG	Eucalyptus occidentalis	Scuddan WA/12476
PGP	Acacia cyanophylla	Timmers + Leyer/
YPB	Eucalyptus microtheca	Coober SA/13200
GWP	Acacia segel	Isiolo
YYR	Eucalyptus microtheca	Kunumurra WA/13359
RRG	Eucalyptus camaldulensis	Ord River/12352
GGY	Proposis juliflora	Setropa
YYY	Eucalyptus occidentalis	Katanning WA/9902
YYP	Eucalyptus salmonophloia	Mt. Martin WA/9919
C	Grevilea robusta	Riakanau
YRW	Eucalyptus maculata	Monta QLD/6164
BWR	Acacia pendula	Charleville QLD/13482
RPY	Eucalyptus astringens	Dryndra WA/12842
PRP	Cassia sturtii	Israel
PWB	Albizzia lebbek	Timmers + leyers
PWY	Acacia senegal	Timmers + leyers
YYB	Eucalyptus oleosa	Norseman WA/9910
WYW	Balanites aegyptiaca	Mutonga
WRB	Casuarina glauca	Wardell NSW

The layout of the trial at Gategi.

YYR	RBW	PRR	YYP	WBP	PYY	BYY	WPP	YWB	WYR	BGG	RRG	YRB	PWY	RGW	WRB	RYW
BWR	GYP	GGY	YRW	RPY	YPR	BGW	GYG	YPG	WBW	RYP	C	YPB	PGW	BYB	WGR	RBG

PRP	WBP	YYB	BYY	RYP	C	YPY	RYW	GYG	YYY	RGW	WGR	PGP	RPR	YPG	YYP	GYP
RBW	A	PYR	PGW	YPR	RRG	WPG	YYR	WBW	WPP	YPB	WYR	BYB	YRB	RBG	B	PWY

GGY	BYY	RYP	WPP	BWR	YPG	C	BYG	BYB	RRG	YRB	YRW	YWB	WRB	RGW	RPY	WGR
PGW	GYP	WBP	PWY	GYG	PRP	RYW	RBG	YYR	PYY	WPW	RBW	PWB	WYR	YRB	YYP	YPR

RPG	BGW	RPR	RPY	YRW		GWY	PPG	WRB	BBW	YYP	PYR	YYR	YYY	BRR	RYR
GYG	WPG	YPG	WYR	RRB	GWR	YPR	YPY	WPP	D	BBB	WB W	PWB	RYW	YPG	YRB

PGP	PWY	WYR	PGW	WGR	RGW	A	GWP	RBG	RPR	GYP	GYG	WBW	RYP	YRB	BYY	YYR
YPR	WPP	C	WPG	WBP	YYY	YPG	YPB	YYP	YPY	RRG	RBW	RYW	BYB	B	YYB	PYR

N ←

Appendix II b List of Australian species planted at Lanciatholio in April 1989

CODE	SPECIES	PROVENANCE	BATCH NO
A. AMPL	Acacia ampliceps	Yilyarra WA	15702
A. ANEU	A. aneura	Charleville QLD	13481
A. AURI	A. auriculiformis	Noogoo swamp NT	16147
A. BRAS	A. brassii	Heathlands QLD	16134
A. COWL	A. cowleana	Hooker creek NT	14634
A. DIFF	A. difficilis	Donydji NT	16173
A. ERIO	A. eriopoda	Broome WA	17164
A. GLAU	A. glaucocarpa	Gayndah QLD	15473
A. HEMI	A. hemignosta	Halls CK WA	14657
A. HOLW	A. holosericea	Carranya WA	14651
A. HOLG	A. holosericea	Coopers CK NT	16389
A. JULI	A. julifera	Balres CK QLD	14974
A. LEPT	A. leptocarpa	MT. Molloy QLD	14139
A. LIGU	A. ligulata	?*! NT	15066
A. MACO	A. macochieana	Tanami dns NT	15747
A. MONT	A. monticola	Smith Hstd NT	17333
A. PACH	A. pachycarpa	Sturt creek WA	15749
A. PELL	A. pellita	Beagle Bay WA	17069
A. PLAT	A. platycarpa	Fitzroy Cg WA	17182
A. PLEB	A. plectocarpa	Spillway CK	17499
A. SALI	A. Salicina	Mitchell QLD	15465
A. SHIR	A. shirleyii	Hidden V. NT	14625
A. STEN	A. stenophlla	Sturt creek WA	17497
A.TORW	A. torulosa	Chillago QLD	14183
A. TORW	A. torulosa	Elliot NT	17490
A. TRAC	A. trachycarpa	Degrey river WA	15767
A. TUMG	A. tumida	Broome WA	17046
A. VICT	A. victoriae	Clermont QLD	15559
E. CHIP	E. chippendalei	Uluru NT	14040
E. MIRC	E. mircrtheca	Rockhmpton QLD	15944
E. ODON	E. odontocarpa	Tennant Ck.	17485
G. PTER	G. pteridifolia	Heathlands QLD	16133
G.STRI	G. striata	Alice spring NT	17254
S. FORM	Sesbania formosa	Beagle bay WA	15752

Layout of Aciar species planted in April 1989

Block I

A.VICT A. VICW E.CAML A.TUMW
A.PELL A.ANUE A.ERI A.PLEB
A.ERI EODON E.CHIP A.PLAT
A.LPET G.PTER A.PLEW E.MICR
A.GLAU A.COWL A.PLEB E.CAML
A.HEI A.TUMW A.JULI A.AURI
A.TORG G.STRI A.HOLG A.STEN
A.SALI A.HOLW A.SHIR A.VICT
A.AMPLI A.VICW A.MONT A.BRAS
ATORN A.MACO S.FORM A.LIGU
A.TRAC A.PACY A.SCLE A.PELL
A.COWL E.ODON G.PTER A.HOLG
A.TRAC A.STEN A.HOLW A.TORW

Block II

(termites)
A.COWL A.MONT
A.PLAT A.PLEW
E.MICR G.STRI
A.AMPL A.SCLE
ABRAS A.AURI A.PACY A.HOLW
A.DIFF A.HOLG A.JULI A.MACO
E.CHIP A.HEMI G.PTER A.TRAC
A.SALI A.STEN A.LIGU EODON
A.SHIR A.TORW S.FORM A.GLAU
A.ERI A.SCLE A.COWL A.HOLW
A.PELL M.AZED A.HOLG A.TORN

A.TUMW A.PLEW G.STRI A.SALI
A.GLAU A.JULI A.MONT APACY
AVOCW A.PLEB A.AMPL ASHIR
A.BRAS A.PELL A.LIGU E.MICR
A.HEMI A.DIFF A.TORG A.ERI
A.AURI A.ANEU E.CAML A.PLAT
E.CHIP A.VICT A.LEPT A.SCLE

Block III

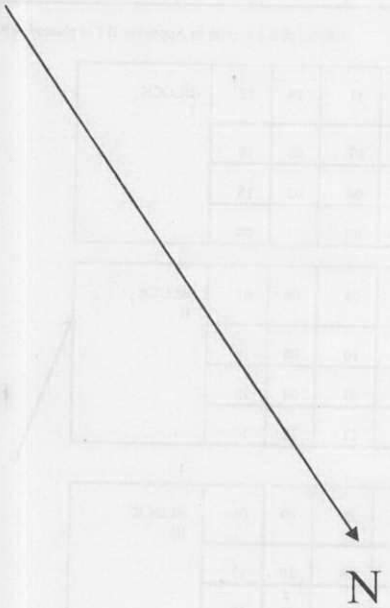
A.JULI E.CAML E.MELO E.MICR
E.DON A.AMPL A.TORG A.PACY
A.LIGU AGLAU A.ANEU G.STRI
A.LEPT A.DIFF A.SALI A.AURI
A.GLAU
A.PLEB A.VICW A.MONT A.STEN
A.GLAU A.VICW E.CHIP APLEW

Block IV

N

Appendex II c Australian species planted in Nov. 1989 at Lanciathurio.

	CODE	SPECIES	PROVENANCE	BATCH NO
01	A. AMPL	Acacia ampliceps	Yilyarra WA	15702
02	A. ANEU	A. aneura	Charleville QLD	13481
03	A. AURI	A. auriculiformis	Noogoo swamp NT	16147
04	A. BRAS	A. brassii	Heathlands QLD	16134
05	A. COWL	A. cowleana	Hooker creek NT	14634
06	A. DIFF	A. difficilis	Donydji NT	16173
07	A. ERIO	A. eriopoda	Broome WA	17164
08	A. GLAU	A. glaucocarpa	Gayndah QLD	15473
09	A. HEMI	A. hemignosta	Halls CK WA	14657
10	A. HOLW	A. holosericea	Carranya WA	14651
11	A. HOLG	A. holosericea	Coopers CK NT	16389
12	A. JULI	A. julifera	Balres CK QLD	14974
13	A. LEPT	A. leptocarpa	MT. Molloy QLD	14139
14	A. LIGU	A. ligulata	?*! NT	15066
15	A. MACO	A. maconchieana	Tanami dns NT	15747
16	A. MONT	A. monticola	PT Smith Hstd NT	17333
17	A. PACH	A. pachycarpa	Sturt creek WA	15749
18	A. PELL	A. pellita	Beagle Bay WA	17069
19	A. PLAT	A. platycarpa	Fitzroy Cg WA	17182
20	A. PLEB	A. plectocarpa	Mann River NT	16187
21	A. SALI	A. plectocarpa	Spillway GreekWA	17499
22	A. SHIR	A. salicina	Mitchell, QLD	15465
23	A. SCLE	A. sclerosperea	Barradale, WA	15774
24	A. SHIR	A. shirleyii	Hidden Valley, NT	14625
25	A. STEN	A. stenophylla	Sturt creek,WA	17497
26	A. TORG	A. tourlosa	Elliot, NT	17490
27	A. TRAC	A. trachycarpa	Degrey River, WA	15767
28	A. TUMW	A. tunida	ENE Broone WA	17046
29	A. VICT	A. Victoriae	Bet Cleromont	15559
30	A. VICW	A..Victoriae	Alice springs NT	15463
31	E. ODON	E. odontocarpa	Stennant Creek NT	17485
32	E. CAML	E..camadulensis	E of P.Ford, QLd	14338
33	E. CHIL	E..chippendalei	W of Uluru, NT	14040
34	E..MELO	E. melonophoia	Mitchell, QLD	17005
35	E. MICR	Eucalyptus microtheca	Rockhampton, QLD	15944
36	G. PTER	Grevillea pteridifolia	Heathlands, QLD	16133
37	G. STRI	Grevillea striata	Alice Springs, NT	17290
38	M. AZED	Melia azedarah	Kenilworth QLD	17390
39	S. FORM	Sesbania formosa	Beagle Bay WA	15752



Layout for appendix II c

			A.SALI
		A.JULI	A.SHIR
		G.STRI	A.MONT
		A.ERIO	A.MONT
		A.TORW	A.DIFF
Block IV		E.CHIP	A.ANEU
		A.MACO	A.PLEB
		A.TUMG	A.VICT
		A.LiGU	A.HOLG
		A.HOLW	A.HEMI
	A.GLAU	A.COWL	S.FORM
	E.MELA	APELL	A.TORG
	A.STEN	A.AMPL	A.TUMW
	A.PACH	A.AURI	E.MICR
	X	X	A.PACH
	A.TUMG	E.MICR	E.MELA
	A.TORW	A.GLAU	S.FORM
	A.LEPT	A.HOLW	A.TUMW
Block III	A.PELL	A.HEMI	G.STRI
	A.MONT	AERIO	ATRAC
	ACOWL	A.STEN	A.AMPL
	A.LIGU	A.ANEU	ECHIP
	X	X	A.SHIR
	ATORG	A.LIGU	A.PACH
	APELL	A.COWL	A.PACH
	ANEU	A.AMPL	A.TUMW
	AHEMI	A.BRAS	S.FORM
	A.JULI	A.SALI	A.PLEB
BLOCK II	AGLAU	E.CHIP	A.VICT
	A.TUMG	A.HOLW	A.TRAC
	A.ERIO	A.MONT	A.HOLG
	A.TORW	E.MELA	A.MACO
	E.MICR	A.STEN	A.DIFF
Block I			
E.MELA	A.GLAU	AHOLG	A.PELL
A.TUMG	S.FORM	A.LIGU	A.BRAS
A.TUMW	A.HEMI	A.COWL	E.MICR
A.JULI	G.PTER	A.LEPT	A.NEU
A.ERIO	A.TORG	A.MONT	A.TRAC
A.PLEB	A.SHIR	A.MACO	A.AMPL
A.AURI	A.PACH	A.HOLW	A.STEN
E.CHIP	A.SALI	A.TORW	A.VOCT

Appendex II e List of central American species tested at lanchiathurio lanted in April 1989.

	SPECIES	PROVENANCE	BATCH NO
01	Gliricidia sepium	Mexico	38/85
02	Caesalpina velutina	Guatemala	57/87
03	Cassia siamea	Embu, Kenya	n/a
04	Senna atomaria	Honduras	25/83
05	Cassia siamea	Thailand	n/a
06	Pithecelobium dulce	Honduras	63/87
07	Ateleia herbert-smithii	Nicaragua	14/82
08	Albizia guachepele	Guatemala	56/87
09	Grevillea robusta	Meru, Kenya	n/a
10	Acacia holosericea	Broome, Aust	17165
11	Eucalyptus camaldulensi	Petford	15223

Layout of central Americamspecies for II e

08	04	01	BLOCK III
06	03	05	
06	02	09	

01	04	05	BLOCK II
07	06	02	
11	02	10	

09	08	07	BLOCK I
06	05	04	
03	02	01	

Appendix II f list have mixed species at lanciatholio planted in Nov. 1988

	SPECIES	PROVENANCE	BATCH
01	Acacia holosericea	Broome WA Aust.	17165
02	Acacia Victoriae	Clermont QLD Aust.	15559
03	Albizia guachepele	Motagua V. Guatemala	56/87
04	Azadirachta indica	Isiolo Kenya	n/a
05	Cordia sinensis	Isiolo Kenya	n/a
06	Cordia African	Muthara Meru Kenya	n/a
07	Caesalpinia velutina	El rancho Guatamala	57/87
08	Eucalyptus camaldulensis	Petford Aust.	15223
09	Eucalyptus camaldulensis	Katherine Aust.	15235
10	Grevillea robusta	Muthara, Meru Kenya	n/a
11	Lonchocarpus eriocalyx	Tharaka, Meru Kenya	n/a
12	Melia volkensii	Gangara, Embu Kenya	n/a
13	Prosopis juliflora	Baobab farm Kenya	n/a
14	Prosopis pallida	Baobab farm Kenya	n/a
15	Pithecelobium dulce	La paz Honduras	63/87
16	Melia azadirach	Comayagua Honduras	25/83

Layout of the species in Appendix II f iv planted in Nov.1988

10	11	14	13	BLOCK I
03	07	05	16	
12	04	02	15	
06	09	01	08	

02	05	06	01	BLOCK II
12	10	08	14	
09	03	04	13	
07	11	15	16	

04	16	09	01	BLOCK III
05	06	10	15	
02	14	12	11	
03	13	08	07	

Appendix II g Muramba seed stand

CODE	BATCH NO.
1	14541
2	14324
3	14377
4	14387
5	14373
6	14540
7	14382
8	14322
9	14385
10	14242
11	14376
12	14801
13	14321
14	14780
15	15320
16	14796
17	14795
18	15318
19	14379
20	14319
21	14390
22	14255
23	14323
24	14317
25	14307
26	14268
27	14311
28	14325
29	14253
30	14783

Layout of the seed stand.

24 04 05 08	01 16 24 23	08 22 25 05
16 01 09 03	05 09 04 15	21 03 09 29
24 19 11 18	08 20 02 11	17 13 20 14
02 15 12 26	03 06 10 19	06 01 10 02
20 23 17 25 VI	30 16 24 12 XII	28 20 11 01 XVIII
06 30 28 29	27 18 26 07	07 30 15 27
10 27 13 21	17 25 22 21	24 23 19 16
19 07 14 22	28 29 13 14	12 26 18 11
08 21 29 25	27 26 15 24	18 23 27 15
25 09 22 03	05 01 23 04	16 26 24 30
20 02 08 17	16 08 07 11	02 12 24 30
07 10 13 06 V	09 06 10 02	01 08 03 28
07 04 05 16	13 17 03 20 XI	22 08 05 13 XVII
15 28 01 23	14 28 12 19	03 29 14 09
30 27 11 12	27 29 22 18	20 11 25 10
19 24 26 18	25 30 26 21	06 19 21 07
29 27 23 16	28 22 27 11	16 26 12 18
08 26 19 04	18 19 12 26	23 11 24 27
18 24 28 17	30 15 04 28	15 28 19 30
12 11 30 06	24 23 07 16	01 17 04 07
07 15 20 14 IV	10 20 06 17 X	06 09 22 13
01 05 10 13	09 05 21 13	14 20 05 10
25 09 29 02	14 08 29 25	08 02 29 22
03 08 21 22	02 03 01 22	09 03 21 25
11 28 16 13	05 04 21 03	08 16 24 09
12 17 26 27	22 02 08 29	23 22 15 05
25 18 20 29	25 14 05 13	01 04 21 12
10 19 30 23	20 09 10 06	03 18 11 02
02 01 06 23 III	01 17 04 19 IX	27 10 20 26 XV
02 01 06 08	07 30 28 16	30 01 05 06
05 04 03 07	11 23 27 18	29 07 25 19
12 11 14 22	15 26 12 24	13 17 28 14
02 25 16 24	07 28 18 11	26 16 08 18
25 21 09 15	30 27 24 26	27 23 12 21
03 23 30 28	07 27 19 12	19 30 12 21
26 27 18 22	16 28 17 10	07 01 28 15
12 11 19 17 II	15 06 04 01 VIII	17 12 07 04
04 01 06 07	20 08 13 05	10 09 06 05
02 08 20 05	14 29 25 21	25 20 22 13
10 14 13 29	02 03 09 22	02 03 29 14
04 21 09 15	10 13 25 03	12 08 21 16
11 22 02 16	29 22 21 09	18 09 03 25
29 24 25 03	02 14 20 13	26 11 24 02
05 80 10 13	08 10 05 01	29 19 23 14
20 14 01 13 I	04 07 17 28 VII	20 10 11 27
XIII		
19 27 28 17	16 15 06 30	22 15 10 05
11 18 07 04	23 24 11 26	04 13 01 07
26 23 30 12	18 12 19 27	28 17 30 06

Appendix II h KATHWANA Melia volkensii trials
(i) Melia volkensii provenance trial

Provenance	Batch No.
Gangara (G)	1091701
Kalulini (K)	1044701
Mbololo (M)	1081701
Voi (V)	1081701
Marimanti (MA)	1101701
Kiritiri (KI)	1092701
Isiolo(I)	1073701

Layout of appendix II h

N

xxxxxxxxGxxxxxxx xxxxxx:xMxxxxxxxx

xxxxxxxxVxxxxxxx xxxxxxxxIxxxxxxxxx

xxxxxxxxMxxxxxx xxxxxxxxVxxxxxxxx

xxxxxxxxxKxxxxx xxxxxxxxGxxxxxxxx

xxxxxxxxKxxxxxx xxxxMxxxxxxx

xxxxxxxxxxxxxxx xxxxxxxxGxxxxxxx

I(1) KI (4)

MA(2) V(3)

xxxxxxKxxxxxx xxxxxxxxxxxxxxxx

xxxxxxMxxxxxxx xxxxxxxxGxxxxxxxx

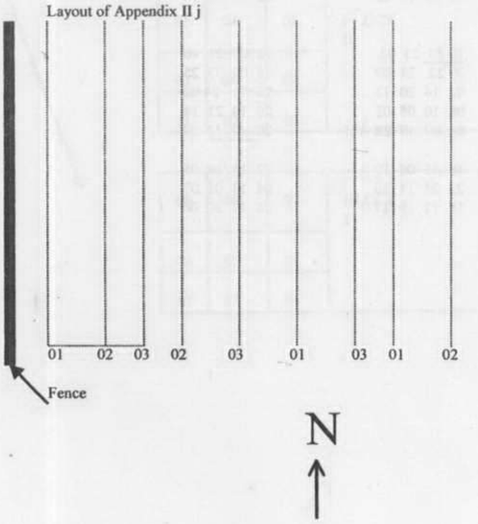
xxxxxxxVxxxxxxx xxxxxxxxxVxxxxxxx

(1) one seedling of (I) used in this line above the codes
KI (4) Four seedlings of (KI) used in the line above the codes
MA(2) two seedlings used of (MA) in the line this below the codes
V(3) Three seedlings of (v) used in the line below the codes

Appendix II j Melia volkensii cuttings and seedlings trial

Code	Treatment	Batch No.	Provenance
01	Cuttings	1096811	Kaunguni
02	cuttings	1096813	Kaunguni
03	Seedlings	1096813	Gangara

Layout of Appendix II j



Appendix II k Melia volkensi progeny trial

Index	Provenance	Batch No.
01	Meru national park	1104815
02	Meru national park	1104813
03	Meru national park	1104811
04	Meru national park	1104814
05	Kalulini	1044814
06	Mtitu Adei	1043814
07	Kalimane	2152811
08	Kalimane	2152812
09	Mwingi	1051812
10	Kaluluni	1044814
11	?	1073701
12	Kaluluni	1044812
13	Katse	1053816
14	Maruria	1097813
15	Madogo	1061813
16	Voi	1081701
17	Kaluluni	1044811
18	Meru National Park	1103813
19	Mutitu Adei	1043813
20	Kaluluni	1044701
21	Mikuyuni	1054811
22	Gangara	1096815

Layout of the above trial (single tree plot)

12	1	3	2	10	5	7
3	5	1	13	2	12	10
5	2	10	3	1	11	12
10	4	5	1	13	3	2
8	1	6	2	3	5	12
1	2	5	3	2	14	12
3	15	9	8	5	10	1

Block II

13	1	10	3	11	12	5
11	5	17	9	3	1	12
18	18	12	5	7	10	1
12	5	1	19	17	8	13
10	12	8	20	1	5	21
22	10	1	5	22	10	5
1	5	22	21	10	22	12

N ←

NB this was a single tree plot

Appendix II L Central American Species Tested at Nkando planted in April 1990

CODE	SPECIE	ORIGIN	PROVENANCE	BATCH NO	SUPP LIER
A. GUA	Albizia guachepele	Guatemala	Motagua valley	56/87	OFI
A. HER	Ateleia herbert-smithii	Nicaragua	La india	14/82	OFI
B. QU1	Bombacorpsis quinatua	Hondura	Choluteca	24/81	OFI
B. QU2	Bombacorpsis quinatua	Nicaragua	Tecolostote	28/83	OFI
C. CAL	Calliandra calothyrsus	RR?			
C. VEL	Caesslpinia velutina	Guatemala	El Rancho	57/87	OFI
E. CAM	Eucalyptus camaldulensis	Australia	Petford	15223/87	CSIR O
C. CAL	Caesalpinia calothyrus				
S. ATO	Melia volkensii	Kenya	Gangara, Embu	N/A	EMI
P. DUL	Pithecellobium dulce	Hondura	La paz	25/83	OFI
S. ATO	Senna atonaria	Honduras	Canayagua	30/83	OFI
C. ERI	Caesalpinia eriostacus	nicaragua	La india	30/83	OFI

KEY OF SEED SUPPLIER
OFI-Oxford Forestry Institute, UK
KEFRI-Kenya Forestry Research Institute, Kenya
CSIRO-Centre for Scientific and Industrial Research Organization, Division of Forestry and forestry products
EMI-Embu-Meru-Isiolo forestry project

Layout of Appendix II L

BLOCK III

C ERI	P. DUL	B. QU1
B.QU2	A. HER	C. CAL
M.VOL	E. CAM	S. ATO
A.GUA	G. SEP	C. VEL

BLOCK II

B.QU1	M. VOL	A. GUA
G.SEP	C. ERI	A. ATO
C.VEL	A. HER	B. QU2
P.DUL	E. CAM	C. CAL

BLOCK I

A.HER	E. CAM	A. GUA
S. ATO	B. QU2	P. DUL
M.VOL	C. ERI	C. VEL
G. SEP	C.CAL	B. QU1

Appendix II m Central American species trial planted Nov.1989 at Nkando

Key	Species	Origin	Provenance	Batch No.	supplier
A.GUA	Albezia guachephala	Guatemala	Motagua valley	56/87	OFI
C.VEL	Caaesalphinia velutina	Nicaragua	La India	14/82	OFI
E.CAM	Eucalyptus camaldulensis	Guatemala	El Rancho	57/87	CSIRO
E.CYC	Entorobium cyclocarpum	CSIRO	Pet ford	15223/87	OFI
G.ROB	Grevellea robosta	Kenya	N/A	21/83	EMI
M.VOL	Melia volkensii	Kenya	N/A		EMI
P.DUL	Pithecelobium dulce	Honduras	La Paz	63/87	OFI
S.ATO	Senna atomaria	Honduras	Comayagua	25/83	OFI

Layout for Appendix II m

Block IV

M.VOL	E.CYC	P.DUL.
E.CAM	G.ROB	C.VEL
S.ATO	A.GUA	A.HER

Block III

A.GUA	S.ATO	M.VOL
P.DUL	A.HER	E.CAM
G.ROB	C.VEL	E.CYC

Block II

A.HER	E.CYC	P.DUL
E.CAM	A.GUA	C.VEL
S.ATO	G.ROB	M.VOL

Block I

C.VEL	E.CAM	S.ATO
P.DUL	A.HER	G.ROB
A.GUA	M.VOL	E.CYC

Appendix II n Austrialian Spp tested at Nkando

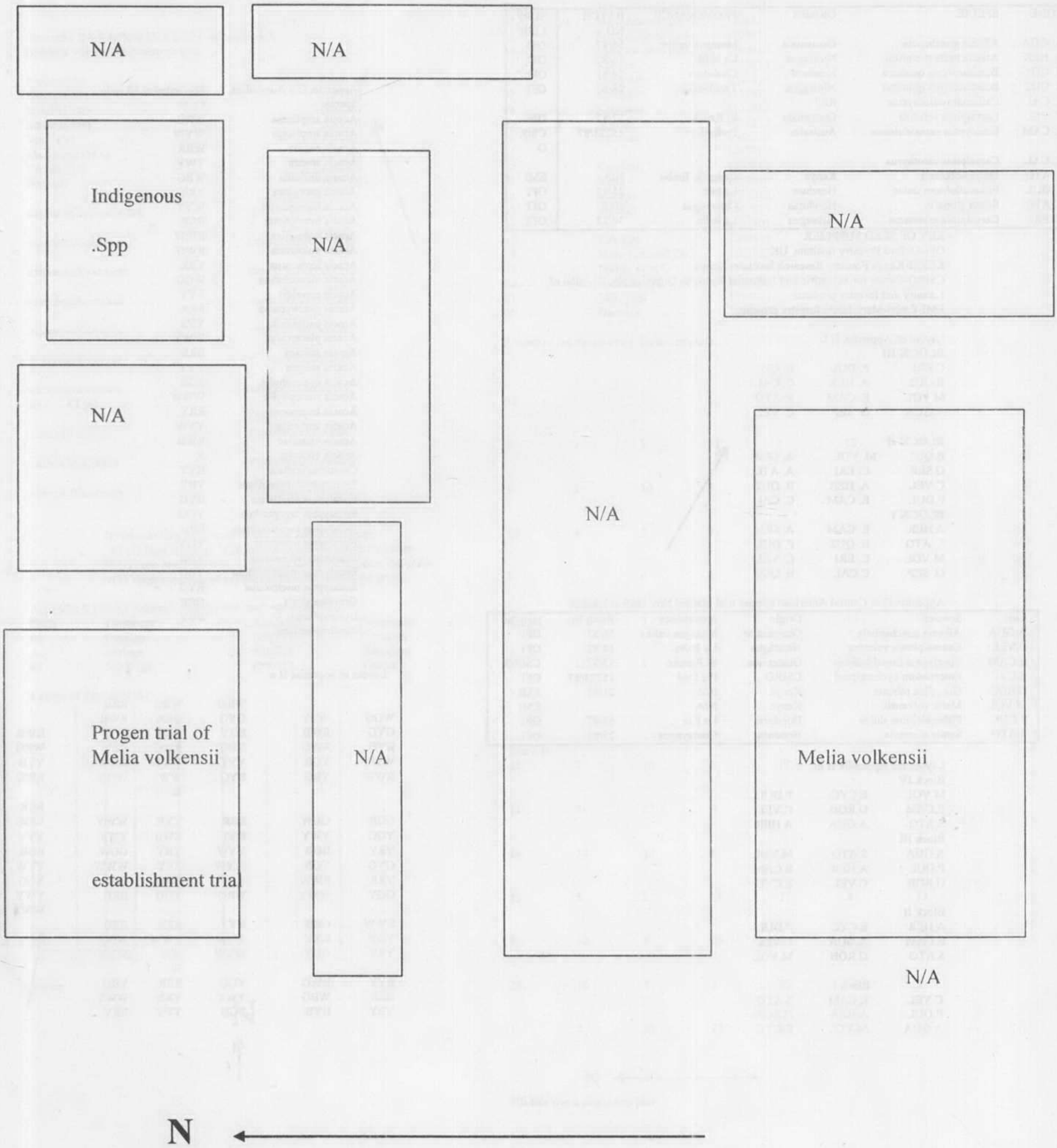
Species	Code
Acacia ampliceps	WRG
Acacia ampliceps	WYW
Acacia anuara	WBR
Acacia anuara	YWY
Acacia difficilis	WBG
Acacia georginea	YRY
Acacia harpophylla	WYY
Acacia hemignosta	BBB
Acacia holoserica	RWW
Acacia holoserica	RWG
Acacia leptocarpa	YRR
Acacia monocheana	WGG
Acacia oswaldii	RYY
Acacia panchycarpa	RRR
Acacia pallidifolia	YYR
Acacia plectocarpa	WWY
Acacia salicina	BRR
Acacia saligna	YYY
Acacia cyanophylla	BGB
Acacia stenophylla	WWW
Acacia latenscens	RRY
Acacia umbrellata	YYW
Acacia victoriae	RWB
Acacia victoriae	X
Causurina cristata	BYY
Eromophylla bignoflora	YBY
Eucalyptus argillacea	BYG
Eucalyptus argopholoia	YGG
Eucalyptus camaldulensis	BRB
Eucalyptus intertexta	YGY
Eualyptus leptophloia	YBB
Eucalyptus melanophloia	YBG
Eucalyptus microtheca	BYG
Grevelea strata	GRR
Lysiphyllum cunninghamiana	BBY

Layout of appendix II n

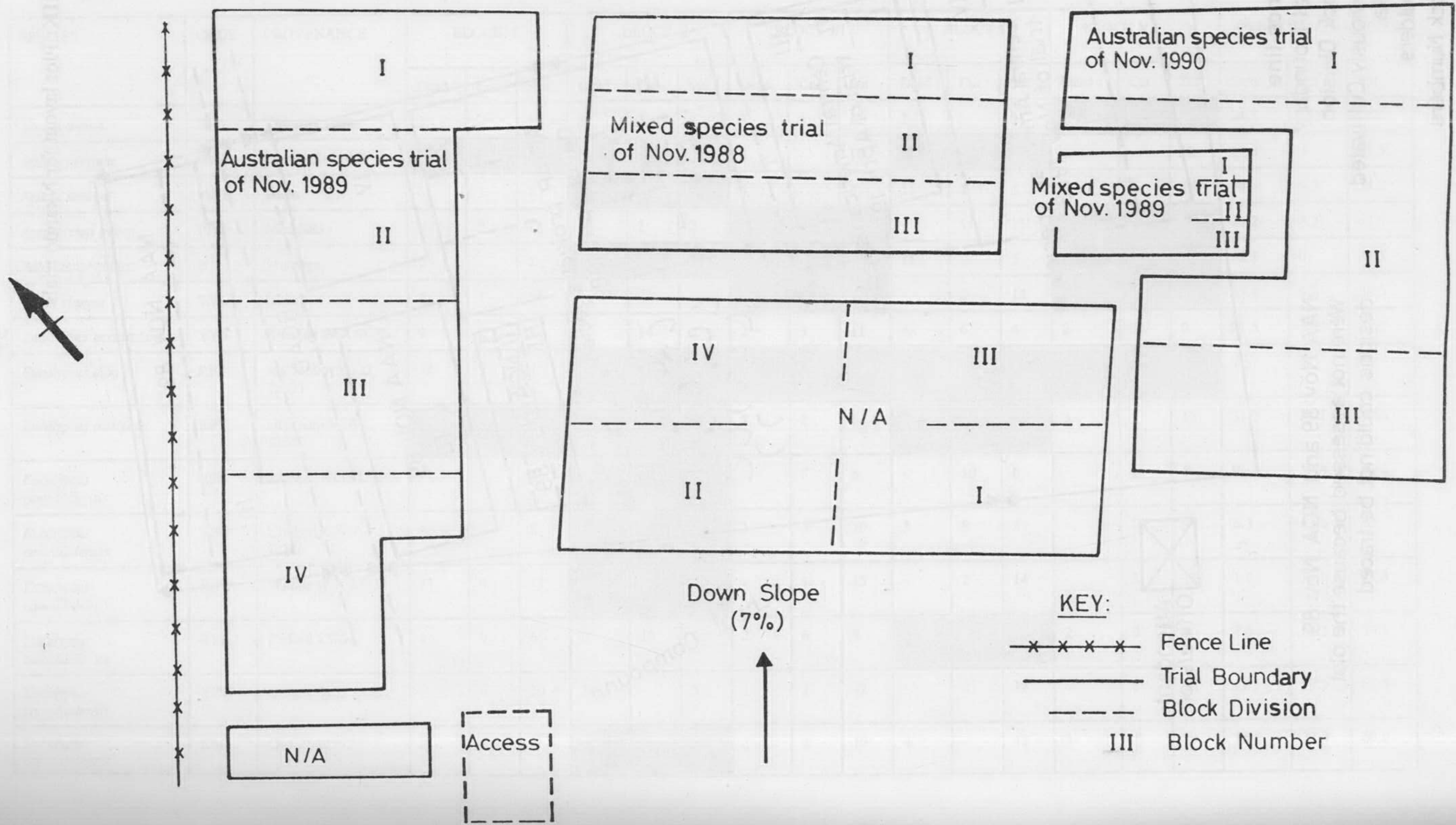
		WRG	WBG	RRR		
WGG	WYY	GYG	GRR	RWB		
GYG	RWB	BBY	WBR	BGB	RWB	BBY
BYG	RWG	YBG	RWG	RRY	WRG	RYY
WWY	YGB	YYY	WYW	RWW	YYB	RRY
RWW	YBG	BYG	WW W	WGG	RWG	GRR
					RRR	WYY
GGR	GGW	BRR	YYR	WWY	WGG	WWW
YGG	YWY	BBY	RWB	YWY	YYY	GYG
YRY	BGB	YYW	YBY	GGW	BGB	BYG
GYG	YGB	WYW	RRY	WWW	YYW	BRR
YRR	RWW	WBG	GRR	WBR	YGG	YGB
GGY	WWY	WRG	YGG	BRR	YWY	WYW
					WBG	WBR
RWW	GRB	YYY	RRR	BBB		
YGY	RYY	WBR	YWW	WRG		
YRY	GGY	WYW	WW W	WYY		
BYY	RWG	YGG	RRR	YBG		
BRR	WBG	YWY	YRR	WWY		
YBY	BYB	BGB	YYY	RRY		

Appendix II o Plots layout for Kathwana trial

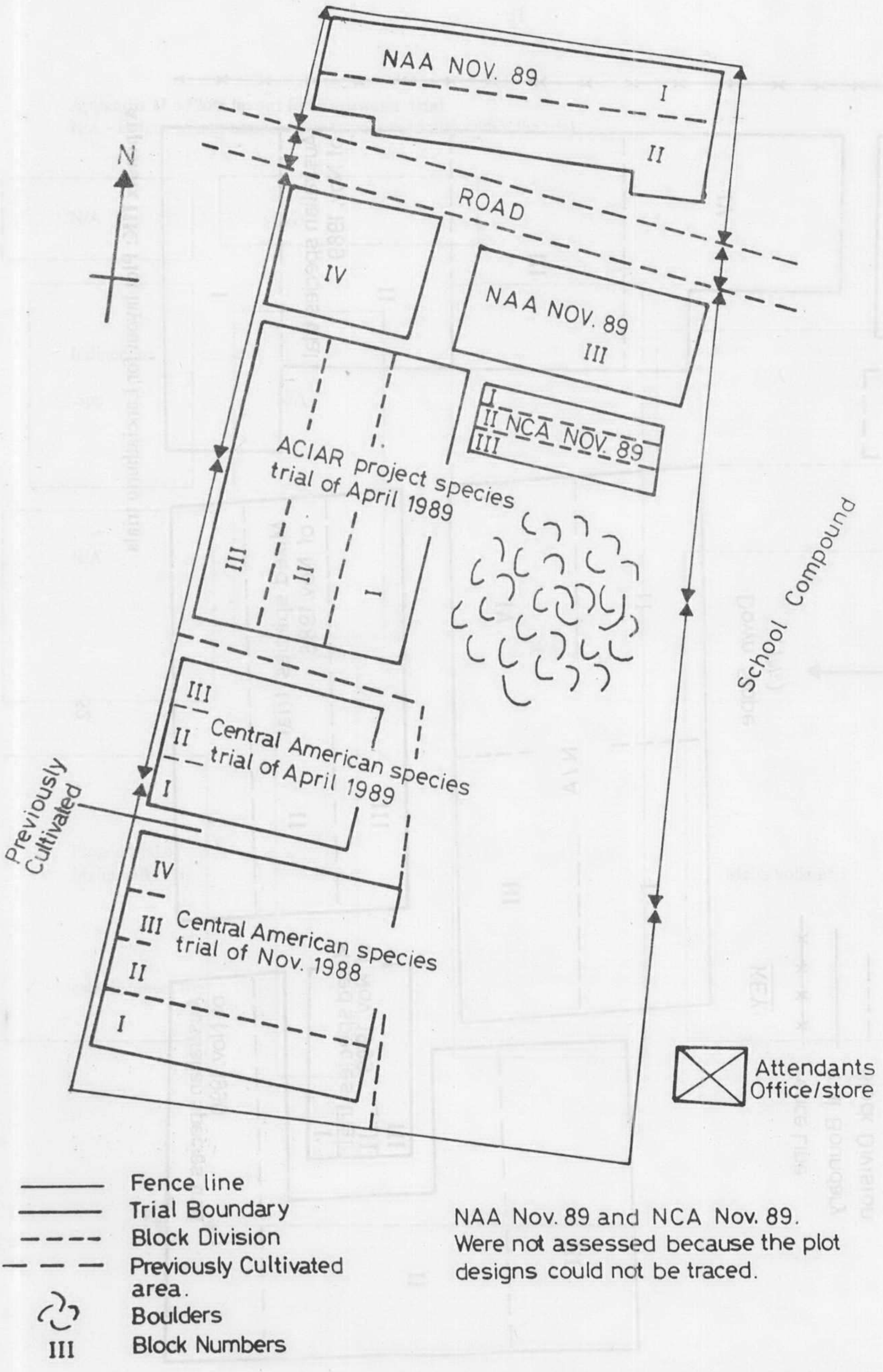
N/A - Refers to non assessed due to poor mortality within the trial..



Appendix IIK: Plot layout for Lanciathurio trials



Appendix IIK: Plot layout for Nkando trials



NAA Nov. 89 and NCA Nov. 89. Were not assessed because the plot designs could not be traced.

Appendix III : List of species that were tested at Gategi. Shaded areas indicate missing plots either at Planting time or due to mortality

SPECIES	CODE	PROVENANCE	BLOCK I			BLOCK II			BLOCK III			BLOCK IV			BLOCK V			PERCENTAGE MEANS		
	•		Dead	Cut	Sur	Dead	Cut	Sur	Dead	Cut	Sur	Dead	Cut	Sur	Dead	Cut	Sur	Dead	Cut	Sur
Acacia indica	BBB	Timmers Leyer	5	-	11	5	3	8	3	1	12	2	5	9				24.3	13.2	62.5
Acacia pendula	BWR	charleville, QLD							6	-	10				6	-	10	37.5	0	62.5
Acacia senegal	PWY	Isiolo	6	3	7				8	-	8	11	1	4	-	2	14	39.6	6.3	54.2
Azadirachta indica	PPG	Mombasa	1	2	13	13	1	2				-	1	15				29.2	8.3	62.5
Balanitesaeyptiaca	B	Mutonga	9	-	7							11	-	5				62.5	0	37.5
Senna siamea	WPG	Ishiara	1	1	14	16	-	-				-	2	14				35.4	6.3	58.3
Eucalyptus accidentails	YYY	Kitaning W A 9902	9	2	5	-	14	2	2	3	11	4	6	6	2	5	9	21.3	37.5	41.3
Eucalyptus alba	RPR	My Molloy QLD 12993	12	-	4													7.5	0	25
Eucalyptus astrigens	RPY	Dryandra W A 12842							7	8	1				3	1	12	31.3	28.1	40.6
Eucalyptus camaldulensis	RRB	Petford, QLD 13159	-	9	7				-	8	8	-	10	6	-	11	5	0	59.4	40.6
Eucalyptus camaldulensis	RBG	Kimberly, W A 12346	-	8	8				1	3	10	3	8	5	-	7	9	6.3	43.8	50
Eucalyptus camaldulensis	RBW	Wiluna W A 13433	11	4	11				-	1	15	-	2	14	-	3	13	1.6	15.6	82.8
Eucalyptus camaldulensis	RYP	Petford 12964	1	9	6	0	10	6	2	6	8				2	9	5	7.8	53.1	39.1
Eucalyptus camaldulensis	RYW	Gilbert QLD 13564	-	6	10	11	-	5	1	3	12	-	4	12	-	1	15	15	17.5	67.5
Eucalyptus camaldulensis	RRG	Ord. R 12352	-	9	7				3	3	10	4	-	12	3	3	10	15.6	23.4	60.9

Eucalyptus citriodora	RPG	Hughenden 12939										2	5	8				18.8	31.2	50
Eucalyptus citriodora	BYY	Garbet QLD 13628	14	-	2				12	1	3	5	1	10	5	2	9	56.3	6.3	37.5
Eucalyptus angiflorens	YRB	Wilcannia NSW 12775	1	3	12	7	-	9	3	1	12	1	1	14	1	3	12	16.3	10	73.8
Eucalyptus maculata	YRW	Monto QLD 6164							5	3	8				3	5	8	25	25	50
Eucalyptus microtheca	BYB	Wolgett NSW 12172	2	4	10	1	-	15	-	4	12	1	1	14	1	-	15	6.3	11.3	82.5
Eucalyptus microtheca	YYR	Kumurra W A 13359	6	2	8	7	-	9				1	6	9	2	2	12	25	15.6	59.4
Eucalyptus microtheca	YPR	Charleville QLD 12935	-	6	10	3	6	7	-	1	15	1	6	9	1	1	14	6.3	25	68.8
Eucalyptus microtheca	YPY	Laura QLD 13350	1	3	12	6	2	8				-	1	15				14.6	12.5	72.9
Eucalyptus microtheca	YPG	DeGroy R WA 12524	-	2	14	1	14	1	2	1	13	3	7	6	1	2	13	8.8	32.5	58.8
Eucalyptus microtheca		Qulipie QLD							-	7	9							0	43.8	56.3
Eucalyptus microtheca	YPB	Coober S A 13200										1	1	14	1	1	14	6.3	6.3	87.5
Eucalyptus olenza	YYB	Norseman, W A 9910	12	-	4													75	0	25
Eucalyptus slimonophica	YYP	Martin W A 1999	5	-	11	9	1	6	6	8	2	7	5	4	3	2	11	37.5	20	42.5
Eucalyptus tereticimis	RYW	Kennedy QLD 12947	-	3	13				4	5	7	-	-	16	-	1	15	6.3	15.6	78.1
Grevillea robusta	G	Riakamau	14	-	2													87.5	0	12.5
Leucaena leucocepha	GYG	K8	1	-	15				1	2	13	-	-	16	-	-	16	3.1	3.1	93.8
Leucaena leucocepha	GYP	Ena	--	-	16				-	-	16				-	1	15	0	2.1	97.9
Ziziphus mucronata	PYY	Kositei													1	-	15	6.3	0	93.8
Ziziphus mauritania	PYR	Kositei	-	-	16	3	-	13				-	-	6				6.3	0	93.8

Appendix IV: Arbitrary height classes of species tested at Gategi. The classes were based on statistical results.

Less than 5m		**5 - 10m**			**10-15m**			**More than 15m**		
Species	No.	Species	Prov	No	Species	Prov.	No.	Species	Prov	No
Z. mauritania	45	*E. microtheca*	13359	46	*E. tereticornis*	12947	54	*E. maculata*	6164	6
A. lebbek	6	*L. leucocephala*	K8	60	*E. microtheca*	12935	55	*E. citriodora*	12939	8
A. indica	12	*L. leucocephala*	Ena	47	*E. camaldulensis*	13433	53	*E. camaldulensis*	12964	25
A. senegal	21	*E. microtheca*	13360	35	*E. camaldulensis*	12352	39			
		E. populuea	11733	22	*E. camaldulensis*	12346	30			
		E. salmonophloia	9919	32	*E. microtheca*	12172	51			
		E. occidentalis	12476	16	*E. occidentalis*	9902	11			
		E. largiflorens	12775	61						
		A. nilotica	-	29						
		S. siamea	Ishiara	28						
		E. microtheca	12524	46						
		E. alba	12993	6						
		E. oleosa	9910	9						
		Z. mucronata	Baringo	30						
		A. pendula	13482	18						
		B. aegyptica	Embu	12						
		P. juliflora		3						

Appendix V: Number of dead or cut stems and MAI in height of E. camaldulensis provenances for Muramba provenance trial established in November 1990. Nos 1-30 correspond to numbers in Figure 9.

Code	Seed batch No.	No. dead	No. cut	MAI-Height
19	14379	3	0	1.63
13	14321	3	0	1.62
9	14385	1	0	1.46
3	14377	1	0	1.46
2	14324	0	0	1.46
11	14376	3	0	1.43
26	14268	1	0	1.40
8	14322	2	3	1.40
10	14242	3	1	1.38
24	14317	3	0	1.38
25	14307	4	0	1.37
29	14253	2	0	1.37
17	14795	4	2	1.36
27	14311	1	0	1.36
14	14780	2	0	1.35
28	14325	1	0	1.35
21	14390	2	0	1.34
22	14255	1	0	1.33
4	14387	1	0	1.33
23	14323	1	3	1.32
20	14319	2	0	1.31
7	14382	2	0	1.29
16	14796	4	0	1.28
5	14373	3	3	1.28
15	15320	2	0	1.23
6	14540	1	0	1.21
30	14783	2	0	1.21
12	14801	0	0	1.18
18	15318	0	0	1.07
1	14541	4	0	1.03